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MIXED CROPPING IN INDIA

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(With Plates XV to XIX)

PART I

GENERAL CONSIDERATIONS

THE practice of mixed cropping which forms the subject of this article is a peculiar and widely adopted method of cropping in India and one which may indeed be said to mark it off sharply from the agriculture of many other parts of the world. By reason of its widely prevalent character and the large variety of crops and conditions of farming that it covers its importance as a subject for scientific examination and research is as great if not greater than that of many other subjects which have been taken up for study so far. Its importance is greatly enhanced by the fact that it has to be studied from a number of aspects, both scientific and economic, demanding the co-ordinated work of specialists in many branches of agriculture. Moreover such opinions as have been expressed about the practice very few though they have been, are conflicting, some being favourable others quite the opposite. Its almost unique character as a form of husbandry also makes it an exceedingly interesting subject for research. A certain amount of attention has been devoted to it in the past by some of the Departments of Agriculture in the country which have touched some one single aspect or other, mostly the economic. It is a matter of some surprise therefore that the subject should have remained practically unnoticed in this respect for such a long time.

It is perhaps due to the special interest in the subject evinced by Rao Bahadur G. N. Rangaswami Ayyangar, I.A.S., formerly the eminent Millets Specialist of Madras and for some time Principal of the Coimbatore Agricultural College, who published several papers on the subject and stressed the need for a systematic study that brought the matter up for serious consideration. It was soon taken up by the Indian Council of Agricultural Research and was made the subject of a full discussion at the meeting of the Crops and Soils Wing of the Council in the year 1941 at its session held in New Delhi. The discussion was led by Rao Bahadur Rangaswami Ayyangar who was followed by several speakers each of whom dealt with one or more particular aspects of the subject as fully as the occasion would permit. The subject was considered worthy of further study and experiments and to this end the following resolutions were adopted viz., 'The Crops and Soils Wing recommends that Directors of Agriculture in the various provinces and States should : (1) make a list of the mixed cropping practices prevailng in the different

areas within their jurisdiction, indicating the usual proportions in which the crops are mixed and the normal soil and the rainfall conditions of the areas concerned and communicate the same to the I.C.A.R. for further examination by a suitable committee ; (2) undertake experiments designed to compare the yields and economic results of growing the crops in question (*a*) pure, (*b*) mixed in the usual proportions, (*c*) mixed in other proportions and (*d*) their effect on soil moisture ; (3) during the course of these experiments carry on observations to study the interaction of the crops at all stages as regards (*a*) root competition, (*b*) competition for air and light above ground, (*c*) nitrogen content of the soil, (*d*) attack of disease and pests, (*e*) soil moisture content, (*f*) quality of produce and (*g*) protein content.'

In accordance with recommendation (1) above, lists of mixed cropping practices prevailing in the different provinces and States were prepared and furnished to the Council, a task which must have cost much time and painstaking labour to the departments concerned. At this stage it was considered that an article on the whole subject embodying all the information that may be available on the subject together with the accounts of the mixed cropping practices collected and furnished to the Council would prove very useful in connection with the scheme and should be prepared. I had the honour of being invited to undertake the preparation of the article and on my agreeing to do so, the Council conveyed formal sanction to the work being taken on hand in their letter No. F.57/2/42-A, dated the 14th March 1944. This is roughly the background for the preparation of this publication.

The complete file containing the lists of mixed cropping practices received from the different provinces and States was sent to me as well as a copy of the proceedings of the meeting containing abstracts of the speeches made during the discussion. These speeches cover a wide field, touch nearly every aspect of the subject and have been made by scientific specialists and by experienced practical agriculturists hailing from many parts of the country. Their observations form very valuable material and indeed have served as the broad framework which I have tried to fill in. As the abstracts were found very brief and as I considered that the authors might desire to amplify them or correct inaccuracies, I forwarded the extracts to the respective authors, from some of whom further information was also received, more especially in respect of references to published work. All these have been very helpful. The lists of mixed cropping practices constitute somewhat voluminous material containing a mass of relevant information and are probably as comprehensive each in respect of the territory concerned as it may be possible to make it. The information has generally been furnished in tabular form under the different heads specified in the recommendation of the meeting. They have been received from the following provinces and States : the N.W.F. Province, Kashmir, the Punjab, the United Provinces, Bihar, Bengal, Assam, Sind, Bombay, Bhopal, Gwalior, the Central Provinces and Berar, Hyderabad, Orissa, Madras, Mysore, Cochin and Travancore and cover therefore almost the whole of India. These lists have been studied and in respect of many of them further information was also sought and obtained from the respective departments on all points requiring clarification. This large mass of information has been analyzed and the material rearranged and presented with

explanatory remarks regarding special features. This rearrangement is grouped under the main crops of the country, showing with what other crops in what numbers and in what proportions they enter into mixture. They specify for instance, two crop mixtures, three crop mixtures and mixtures with more than three crops, whether these are cereals pulses or other crops, the total number under each of these classes, and in the case of the two crop mixtures the various proportions in which they are mixed. This special treatment has been made in respect of only the main crops and in regard to proportions is limited to the two crop mixtures, from considerations of practical importance, not to mention those of space.

Such literature as could be obtained on the different aspects of the subject meagre though this is, has been consulted and made use of. All the Directors of Agriculture who were consulted to ascertain if any experiments have been conducted on the lines suggested in recommendations (ii) and (iii) of the Council have replied in the negative. Only the few experiments conducted in the past and prior to this discussion have therefore been available and these have been fully utilised and are referred to in the appropriate places. These experiments relate mostly to the Madras and Bombay Presidencies, the Central Provinces and Mysore State. All these sources of information together with such facts as I could gather from my own studies and as have come within my experience as an agricultural officer in Mysore and outside have formed the materials for this article. Wherever necessary and possible the concerned references have been quoted.

The general plan of the article will be seen from the headings given in the contents. The article is divided into two parts, Part I General and Part II Special. Part I describes the forms of mixed cropping and the extent of the practice as compared with pure cropping and the methods of sowing the mixed crops, and then deals with the various different aspects of mixed cropping each in a separate section, viz., mixed cropping in relation to rotation of crops, soil moisture, plant foods, association of cereals and legumes, insect pests and diseases, the use of labour saving implements, balanced nutrition, insurance against crop losses and utilisation of space ; a section on the economics of mixed cropping closes this part. In the main these relationships are the ones which are specified in the Council's recommendations (ii) and (iii) and which have formed the principal heads in the discussions ; they have been accordingly adopted by me as a helpful basis.

Part II contains what I may term the factual foundation for the article. It is devoted to a description of the details of mixed cropping with reference to the chief crops, together with certain relevant observations. These chapters form really a digest arranged according to crops, of the information contained in the lists furnished by the Directors.

Illustrations showing the implements used for sowing mixed crops and fields with mixed crops standing, which have been kindly supplied at my request by some of the Directors of Agriculture have been added. These views relate, it will be seen, to many parts of India and will no doubt be appreciated by readers, both in and outside India.

A somewhat embarassing task has been in connection with the names of the different crops. Each province and State has used its own vernacular and the same crop has been referred to by many names. It has been rather difficult under these circumstances to fix upon any one vernacular or common name for being used throughout. My selection had perforce to be somewhat arbitrary and I trust this will be condoned by readers who may be accustomed to a different vernacular. A full glossary giving the botanical names and the different vernacular names and the common English names where possible has been furnished by each Director with regard to his particular region and this has been added as an appendix.

As one who has ceased to be in active service now for many years I regretfully admit that the article is not as thorough as it might perhaps otherwise be. I have found the work however of absorbing interest and that, together with the hearty co-operation which has been extended to me by the officers of all the Departments of Agriculture to whom I applied have enabled me to make the work as satisfactory as I could. Mixed cropping is a large and unique part of crop husbandry in India and I trust I have furnished a comprehensive connected and readable account of the practice in its various aspects and as it prevails in most parts of the country.

Forms of mixed cropping

In a general way we may define mixed cropping as the system of growing two or more crops (or varieties) in the same field, garden or plantation, not in separate blocks each carrying a single crop but all of them mixed together and occupying jointly the same ground and sharing in common the cultural operations of the field as though the latter were intended for one single crop, and sown or planted either promiscuously in the midst of each other or systematically in alternating rows or otherwise. The cropping may apply to permanent crops of the so-called plantation type or those which occupy the ground for only one crop season whether this be a few weeks, months or a year. The cropping may apply again to a mixture of both these two types of crops, permanent and temporary, the latter being grown either for the sake of its produce or for being ploughed in as green manure or for both. In particular, it is to the temporary or annual crops and even among them to the crops grown on a field scale and comprising the ordinary field crops that the term shoud be confined ; as a matter of fact the large amount of data collected and dealt with in this report relate mainly to this class of crops, and to the systems followed in cultivating them as mixed crops. A brief description may however be given of the mixed cropping methods of the other types also, both for the sake of completeness and for its value in illustrating the principles which underlie the practices.

Mixture of permanent crops

The most common example of this practice can be said to be the mixed fruit

gardens, in which cocoanuts, mangoes, jack, guavas, oranges and other citrus trees mingled with arecanut trees, and all planted generally in a promiscuous manner and very often too crowded to permit of the different trees yielding their best are grown together. These gardens are generally irrigated or (as in some parts of Mysore) are subject to periodical inundations from rivers which overflow their banks. All the cultivation is only by manual labour and this takes the form of a digging once a year at the close of the monsoon. Manure may be carried in headloads and applied, or the yearly addition of silt by the river may be all that is considered necessary. Depending upon the varieties of the trees planted, there is a succession of crops of one kind or another almost throughout the year with of course flush periods now and then. There is also work of one kind or another in the garden throughout the year to occupy the time of the grower. The gardens are highly valued on this account and there is always the temptation to plant something or other extra, a fruit or flower for sale or the owner's enjoyment. The gardens are fully shaded, the crowns of many trees mingle, others carry their canopies higher, resulting in two or more tiers at irregular heights.

The second example is furnished by certain kinds of coffee estates, specially of robusta coffee ; in these a few rows of robusta bushes varying from three to six may be seen planted alternately with one row of oranges, to which may be added a row of pepper trained on shade trees, so that three permanent crops alternate with each other in systematically planted rows. In many coffee estates indeed pepper is a regular feature, growing however trained on the shade tree standards either in a somewhat promiscuous manner, or in regular rows. While in the larger estates, pure crops are the rule with the exceptions noted above such as the growing of pepper and oranges, on the smaller gardens and estates, especially in Travancore, and Ceylon, may be seen quite a mixture of trees as in the irrigated gardens referred to already. These may comprise cocoanuts, arecanuts, cloves, cocoa, coffee and even tea bushes in case there should be a factory near by.

A third example is the growing of the areca palm with the betel vines trained on them as standards. The shade of the areca palms which are planted very close helps the betel vines for which shade is indispensable while the trees themselves furnish the standards for the vine to climb upon. The heavy manuring, irrigation and constant attention received by the betel vine greatly benefits in its turn the areca trees themselves. An example of a different type is furnished by the arecanut gardens of the malnads of Western Mysore, S. Canara and the Konkan, which are unique in respect of the planting and cultivating methods. Areca, cardamoms, pepper and plantains are the crops grown and they are planted in such a way that hardly any ground is wasted Areca trees are planted in roughly three instalments, at intervals of about seven years or ten years, so that they stand about six feet apart in regard to their bases but their crowns are quite clear of each other being almost 15 to 18 feet apart. The trees are thus of three age groups, each group being about seven or ten years older than the one following it in time. When the trees have grown about 15 feet high (exclusive of the crown) pepper vines are planted

under them and eventually trained on the stem as standard. When the garden is ten years old the planting of cardamoms is taken on hand and these are planted all along the margins of the drains, and by periodical renewals these are kept up permanently. Plantains are planted even before the areca is put in, as a preparatory crop to shade and nurse the young areca trees and every year thereafter are systematically kept up by new plantings in between the areca trees, so that there is hardly any vacant space except what is occupied by the drains and the narrow elevated ridges which separate the rows of areca trees and which serve as pathways. The procedure defining exactly the routine of yearly plantings manuring, cultivation attention to drains and ridges is fixed and committed to writing and lease deeds specify the duties of the lessee in detail. This is perhaps the oldest and most clearly defined form of mixed cropping in respect of permanent crops.

Mixing permanent and temporary crops

The temporary crops grown mixed with permanent crops are in the nature of (1) nurse crops, (2) catch crops, (3) green manure crops.

(1) *Nurse crops.* This may be exemplified by the growing of crops like 'bogame dalloa' (*Tephrosia candida*) Crotalaria spp. like striata, juncea, anagyroides *Sesbania aculeata* and such crops between rows of young coffee, and to some extent also tea. These furnish a certain amount of low shade, protecting the young bushes ; they may be removed after a season but are generally kept on for a year or two, being lopped in the interval if necessary, so that the growth of the main crop may not be interfered with. The loppings act also as a green manure and as a soil mulch.

Another example is the growing of plantains in young cocoanut gardens, principally for the sake of protection against the sun. At the same time they serve as profit yielding crop for some years until they have to be removed in the interests of the cocoanut crop itself. Till then by yearly new plantings the plantains are kept on, with advantage to the cocoanut crop and just paying for the expenses of cultivation. It is sometimes claimed that the plantain crop keeps away the rhinoceros beetle from the cocoanut palms ; if it really does so it acts as a nurse crop in more senses than one. A trial was made by the Mysore Agricultural Department to test this point by planting a plantain sucker under every alternate cocoanut plant in the Hebbal Farm but the results showed no difference in regard to the incidence of the attack ; still the belief is somewhat general.

(2) *Catch crops in the midst of permanent crops.* These crops are of very short duration, especially in comparison with the main crop, and are grown until the main crop comes into bearing and only during such time that they can be grown satisfactorily and without detriment to the main crop. They are cultivated for the sake of their produce, and yield a small income, which may often be sufficient to meet the cost of cultivation of the main crops. In young cocoanut gardens, *ragi* (*Eleusine coracana*), *jowar* (*Andropogon sorghum*), Italian millet (*Setaria italica*), groundnuts, or one or other of the many kinds of the quick growing pulse crops like blackgram (*Phaseolus mungo*), greengram (*Phascolus radiatus*) or horsegram (*Dolichos biflorus*) are grown in this manner. A notable practice under this class is the growing of

vegetable crops in among betel leaf gardens ; these gardens are kept up for either a period of three years (in South India) or indefinitely for a long period of even 20 to 30 years (as in Mysore). The gardens are heavily manured and watered. The ground under the vines and the advantage of the intensive cultivation are utilised for the growing of short duration vegetables which yield an income till the vines begin to yield and as long as they can be grown without interfering with the cultivation or yield from the vines.

A third and notable example (although it does not relate to a permanent crop, like the ones considered so far) is the growing of catch crops in the midst of young sugarcane. Where sugarcane is planted on elevated beds about six feet wide and divided by trenches, these beds are sown with radishes, greens, coriander, onions, French beans, etc. and these crops are gathered within 45 to 60 days, and removed. It means a profitable utilisation of the ground without detriment to the sugarcane. The kind of crop to be grown has to be carefully selected for if they are tall growing they are likely to check the growth of the sugarcane. It was once advised that sannhemp (*Crotalaria juncea*) may be advantageously grown in this manner and in preference to the vegetable crops, to be later pulled out and laid on the beds as green manure ; but in many cases this crop was found to check the growth of the cane. The practice was not taken up owing to this risk.

Young orange gardens or plantations, especially under irrigation are systematically inter-cropped with vegetable crops or even cereal crops during the first few years in order to make some profitable utilisation of the ground between the rows of the orange plants whereby a moderate income is realised which may cover the cost of cultivation if not yield a small nett profit. This inter-cropping ceases as soon as the orange plants become bushy, when the irrigation basins have to be enlarged and the inter-spaces will not allow of any such inter-cropping. All through the newly developed *Santra* groves of the C.P. and Bombay and the Northern Circars this kind of cultivation with mixed crop is very general. The same practice obtains in gardens of papayas, although in this case it is only for a year or two as the papayas themselves remain on the ground only for about three or four years.

(3) *Green manure crops.* Some of the crops belonging to above class may comprise green manure crops which in contrast with the former are merely dug or ploughed in and not allowed to mature a crop for sale and conversion into money. The practice is perhaps not a general one, but is adopted wherever it may be considered necessary and advisable to do so, taking into consideration other factors mainly the supply of soil moisture and rainfall. Special mention deserves to be made under this class of the practice which is becoming very prevalent in recent years in rubber estates and which consists in the growing of green manure crops like *Centrocema pubescens, dolichos pueraria phaseoloides*, cow-peas (*Vigna catiang*) or other low growing leguminous crops for this purpose and incorporating them into the soil ; the last mentioned crop viz., the *Centrocema pubescens* acts also as a very good cover crop and is left on the ground almost as a permanent crop where it seeds and regenerates itself naturally. The fairly wide expanse of ground surface between the rubber trees makes such a cropping convenient and the growth of these mixed crops

is usually very heavy and form a very thick cover on the soil. As to the practical advantages of the method as against clean cultivation and ordinary manuring, views differ but we are here referring only to the existence of the practice, the other aspects being dealt with separately.

Mixed cropping with fodder grasses

In quite a separate class comes the sowing of grass seeds and of leguminous fodder grass seeds mixed together for grass land intended to be under permanent or temporary pastures. Both the types of grasses grow together and are mown together and converted into mixed hay, or/and grazed together. This association of not only different grasses but also the legumes with the grasses is advantageous not only in improving the nutritive value of the mixed forage, but may be also said to possess most of the special advantages of mixed cropping such as an assured yield free from seasonal risks, a better utilisation of the soil and also mutual benefit to the different components. It is in fact in connection with these grass mixtures that considerable scientific work on some aspects of mixed cropping has been carried out. Such mixtures are also practised in the case of fodder crops grown as ordinary field crops of one season; a common mixture is that of fodder *jowar* with horsegram to be cut and fed together as green feed. There is likewise the mixture of fodder *jowar* and berseem (*Trifolium alexandrinum*), *shaftal*, cluster beans (*Cyampsis psoria-lioides*) (*Trifolium resupinatum*) and such other leguminous crops, all meant as mixed green fodder.

Extent of mixed cropping

The extent of mixed cropping is very large and certainly forms a conspicuous feature of agriculture in India, so much so that to the observant visitor this is the most striking and interesting feature which marks it out sharply from cultivated areas of Europe or America, and which immediately sets him thinking as to what may be the rationale of such a peculiar feature. Depending upon the temperament of the visitor it is put down to ignorance of the importance of rotation of crops or as a remarkably clever adaptation to the needs of the country full of practical wisdom and worthy of deep study. Though the extent is large and striking it must not be thought that it is universal or that it is invariable and carried on to the exclusion of pure or single crop cultivation. There is no correct information regarding the relative extents of pure and mixed cropping in the different provinces, but from the approximate data furnished by the various departments of Agriculture it may be stated that large as the extent may be, it is however only a fraction of the extent of mixed cropping. For one thing the practice of mixed cropping is largely if not wholly confined to rainfed or dry cultivation, and barring minor exceptions under well cultivation, for example, and some special cases all the irrigated crops are grown pure. Even under dry cultivation there is a very large extent of pure cropping with the very same major crops which figure in mixed cropping. Moreover such information as is available indicates that in some provinces mixed cropping is very insignificant. Thus in the province of Sind it is reported that ' mixed

cropping is not much in vogue in this province. It is only in stray tracts the combination of cotton with *jowar* and *guar* is noticed.' In Jammu and Kashmere it is reported that 'the exact acreage under this mixed cropping is not known but it may be assumed to be about 5,000 acres,' which is certainly very small. In Travancore and Cochin the practice is confined to certain taluks only. In the west coast districts of the Madras Province also i.e., Malabar and South Canara it is stated 'no regular mixtures are grown worth mentioning.' In the report on mixed cropping methods received from the Bombay Province, the West Coast Districts do not figure much at all; in the Malnad Districts of the Mysore State, where the rainfall is as heavy as in these West Coast Districts and rice is the chief crop grown no mixtures are practised. In the report from Bengal, it is stated that in the District of Dinajpur the practice is not much in vogue. In the districts comprised of the Western Circle, Bengal, the extent of mixed cropping in the case of the following crops is reported as under: paddy from 5 to 30 per cent, wheat from 2 to 12 per cent, barley 1 to 25 per cent, gram 15 to 77 per cent, lentils 20 to 77 per cent, peas 1 per cent, *khesari* 20 per cent, *mung* 2 to 20 per cent, mustard 1 to 50 per cent, potatoes 1 to 5 per cent. In the Jullundur Circle, Punjab, mixed cropping amounts to only 15 per cent in cotton, 20 per cent in *jowar*, 20 per cent in maize 10 per cent in *bajra*, 40 per cent in barley, 60 per cent in wheat and 80 per cent in gram. In the Districts of Bihar comprising the *Chota* Nagpur Range, it is stated that mixed cropping is not much in vogue. Even in a province like Madras where the practice is very important, mixed cropping is by no means the rule and it is stated that the ratio of pure to mixed cropping is subject to variation from year to year. In Gwalior State it is reported that the ratio of the acreage of crops grown pure to that of the same crops grown mixed are as in Table I.

TABLE I

Ratio of pure to mixed crops

Serial number	Crops	Ratio of	
		Pure	Mixed
1	*Jowar*	1	1
2	*Bajra* (*Pennisetum typhoidem*)	1	1⅓
3	Cotton	1¼	1
4	Ginjelli (*Sesamum indicum*)	1	2
5	Maize	2	1
6	Wheat	1	1
7	Gram (*Cicer arietinum*)	1	1⅓
8	Barley	1	4
9	Linseed	13	1

Even where mixed cropping is largely practiced many crops are thus grown both pure and as mixed crops. Thus very large areas may be seen where *jowar*, wheat, *bajri*, *ragi*, cotton, castor, gingelli, the different pulses, dry-land chillies etc., may all be seen to be grown pure, although they are the chief crops which are grown as mixed crops.

It may be interesting to note the circumstances which sometimes decide the pure cropping of even those crops which are largely grown with a mixture. In Mysore, in the tracts of early rainfall where the *ragi* called *kar ragi* is grown, it is sown pure, as this enables the field to be ploughed in the late rains, after the harvest of the *ragi*, in which condition the field remains until sowing season next year. Whenever *ragi* is grown by transplanting whether as a dry crop or as an irrigated crop it is grown pure, so as to make it possible to intercultivate the field both along and across, as the plants are transplanted in regular chess board fashion. For the same reason crops like castor, chillies and tobacco although they are sown in the main season and form the only crop of the year are also grown pure. When two crops are raised in the same year one in the early rains and another in the late rains, these are raised generally pure. The pulses like blackgram and greengram are grown pure in this way either in the early or the late rains; the pulse horsegram is grown in the late rain, as likewise Bengal gram. Fodder *jowar*, short-season groundnuts (Spanish or Small Japan) are sown in the early rains pure, because the land has to be ploughed and sown with a second crop in the late season. The late season *jowar* (called *bilijola* in Mysore) is also sown pure, invariably. In all the cases the need for getting the field ready for a late or second crop, and the fact that this second crop has to be of short duration depending as it does upon only the stored moisture of the soil and very little on rainfall, restrict if not preclude the sowing of a mixed crop, one of which may be of long duration and may not therefore thrive on account of lack of rainfall. Among the main season crops which occupy the field the whole season, the American Cotton (called Dharwar American) is grown only pure unlike the local cotton which is grown both pure and mixed. The trailing varieties of groundnuts, also a main season crop and the only crop of the year, is only grown pure. The reason probably is that these two are crops introduced newly into the country (although they have been grown now for probably a century) and have not shared the tradition of mixed cropping unlike the old indigenous crops at any rate so far as Mysore is concerned. It must be mentioned however that elsewhere as in Madras, these are grown both as pure crops and as mixed crops. Thus pure cropping methods prevail over very large regions, even in the case of dry crops (where alone mixed cropping assumes importance) and in respect of the crops which largely figure in mixed cropping and in the case of many short season crops which on this account may be considered fit only for mixed cropping.

Mixed cropping and crop rotation

Some of the remarks made by those who have written in high appreciation of the practice of mixed cropping may lead one to suppose that the system is to be

regarded as a substitute for a rotation of crops and that these mixtures are grown year after year in the same field, because this is a 'tabloid form of rotation,' that it helps more than anything else to maintain the fertility of the soil and so on. As a matter of fact on the other hand the need for and the advantages of a rotation of crops, and conversely the incorrectness of growing the same crops or the mixture of crops on the same field year after year are fully appreciated and it is very doubtful if the system of mixed cropping is adopted because rotation is considered unnecessary under that system. This is clear from the fact that excellent systems of rotation suited to the different local agricultural conditions are everywhere in vogue and are adopted in conjunction with mixed cropping. Dr Buchanan at the outset of his tour when he first noticed a mixture of crops observes that 'the cultivators do not seem to understand the ameliorating effect of rotations' but as the tour progressed and he traversed a large extent of country he has occasion to notice that the contrary is the case and that elaborate rotations are known and followed and with his usual thoroughness he records these rotations. It may be interesting to note down some of these :—'Round Pollachi (Coimbatore District) the following rotations are common viz., first year *bajri* with its mixed crop of pulses, second year *jowar* in the first season followed by horsegram in the last season, third year grass manured by folding with cattle. (*b*) First year *bajri* with its mixed crop, second year *jowar* in mixture with *Panicum miliare* or blackgram or gingelli or green gram in the early season followed by horsegram in the late season, third year grass manured by cattle folding, (*c*) first year *bajri* with its mixed crop, second year cotton with *jowar*, third year cotton of the previous year remains over, fourth year grass manured by cattle folding.

In Mysore similar elaborate rotations are common, although the mixed crop of *ragi* with which field beans (*Dolichos lab lab*) is grown year after year on the same field to a very large extent. A full account of the common rotations is given in the author's book '*Field Crops of India*.' Some of these may be extracted here : viz., in the cotton belt, cotton either local *G. herbaceum* or American is grown pure and is followed by *jowar* grown pure or with a mixed crop of redgram (*cajanus indicus*) but generally a variety of crops including redgram. Where only late season crops are possible, in the black cotton soil belt, cotton mixed with Italian millet is followed in the next year with either late season *jowar* or Bengal gram or wheat. In the red soil *jowar* tract of the Mysore District *jowar* with redgram as a mixed crop is followed by early season *ragi* in the next season, or by mixture of horsegram and niger. After *ragi* with its mixed crop of field beans or redgram or a mixture of several in the first year may come in the next year either the same mixture or short season groundnuts followed by fodder *jowar* in the same year or long season groundnuts only ; in the second or third year only horsegram may be sown or a double crop of fodder *jowar* followed by black or green gram. For nearly every crop whether grown pure or in mixture there is an appropriate rotation crop. These rotations are always followed except where conditions force the *ryot* or make it financially advisable on account of high prices for some produce, to resort to the cultivation of the same set of crops without a change.

Information regarding the rotations prevailing in many of the provinces is given in Appendix III and some are extracted below :

Bhopal. The general practice is first year wheat, second year cotton or *jowar* third year gram. ' There are cases where due to special circumstances they do get away from this rotation but it is only either in a part of the holding or in places where they cannot grow a particular crop due to some reason.'

North West Frontier Province. The following are some of the rotations : (1) Maize—wheat—maize, (2) rice—*shaftal*—maize, (3) wheat—cotton—wheat, (4) gram—*bajra*—gram, (5) maize—berseem—maize, (6) *rice*—wheat—rice, (7) gram—*bajra*—*toria* (*Brassica napis*), (8) maize—tobacco—maize, and (9) wheat—fallow—wheat.

Bombay Province. Mollison's Text book of Agriculture gives the rotations for nearly every crop of importance and it will be seen from his account what a systematic rotations of crops is practised. The following are some of these : (1) *jowar* with mixed crops—cotton, (2) *bajri* with mixed crops—Italian millet or *sundhia jowar*, (3) *bajri* with mixed crops—*jowar* or niger, (4) *bajri* with mixed crops—cotton, (5) wheat cotton—*jowar*, (6) wheat—linseed—gram, (7) *ragi* with mixed crop—*jowar* with its subordinate mixed crops—or Italian millet mixed with redgram and gingelli, (8) sesamum—cotton—*jowar*, (9) niger—hill millets.

A similar condition probably prevails throughout the country, and reports from the provinces concerned give details about the rotations. The point to note however is that along with the mixed cropping system and as part of it regular rotations are practised in which the group of mixed crops of any one particular year is taken as a unit, and is followed by another single crop or group of mixed crops as in any ordinary rotation. The growing of the same crop with its appropriate mixture year after year without a rotation in the same field though practised very largely and in many tracts must be considered special, and should in no sense be taken to mean that rotations are either unknown or not practised and that mixed cropping is adopted as a substitute.

Although it is needless to labour this point further, the following remark by Dr J. A. Voelcker may be found both interesting and valuable, viz., ' It is quite a mistake to suppose that rotation is not understood or appreciated in India.' Dr Voelcker also gives in support of this observation numerous instances of the rotations practised systematically in the provinces of the Punjab, the N. W. F., Bengal, Central Provinces, Bombay and Madras (*Improvement of Indian Agriculture*, pp. 234-236).

How the mixed crops are sown

The methods of sowing adopted in the different provinces show interesting variations depending upon the general level or excellence of the agricultural practices

current in each tract and also on the condition of the soil at the time of sowing. These methods comprise the following :

(*a*) *The sowing is entirely by the method of broadcasting or scattering by hand.* Both the main crop and the crop or crops used for growing in mixture are sown broadcast in this method. In broadcasting itself more than one method is adopted, viz., (1) the seeds of the two kinds of crops are mixed together and the mixture is sown broadcast, and (2) the main crop is first sown broadcast by itself and the field is given a light ploughing or harrowing to cover the seed ; then the mixed crop is sown in the same manner i.e., broadcast and the field lightly ploughed harrowed to cover the seed. This latter practice of sowing the mixed crop after finishing the sowing of the main crop is followed in the case of those crops the seeds of which differ very much in size. Usually the smaller sized seeds are sown in the first sowing and the larger sized seeds are sown in the second sowing. This method of double sowing is adopted in order to secure uniformity in the distribution of the two kinds.

(*b*) *The second method consists of both broadcasting and line sowing.* The main crop generally, a grain crop, is first sown broadcast and covered by a light ploughing or harrowing, then plough furrows are drawn at the desired distances and in these furrows the seeds of the mixed crop are dibbled or dropped by hand. In the alternative the opening of the furrows and the sowing of the seeds may be done in one operation by the use of a one-row drill ; this is tied behind the plough which goes in front opening the furrow, while the seed is dropped through the drill. The mixed crops very often comprise more than one, and then the seeds of all these are mixed and sown in the plough furrows either by hand or through the one-row drill. The broadcasting of the main crop in this manner is adopted even where line sowing is the general practice, when the soil may be too moist and the openings of the seed-drill tynes may become choked with soil and the sowing may become imperfect leading to bare unsown patches here and there.

(*c*) *The sowing may be entirely in rows.* Both the main crop and the mixed crops are sown in lines in this method. This kind of sowing in lines is done almost invariably with the help of seed-drills of various kinds, including the above mentioned one-row drill. The simplest among these practices consists in using only the one-row drill. This is tied behind a plough, which moves forward opening the furrow, into which the seeds of the main crop are dropped through the hopper of the drill. After the customary number of rows of the main crop have been sown, then one row, (sometimes more) of the mixed crop is sown through the same drill, after which the sowing of the main crop rows is resumed ; the same is repeated till the whole field is completed. The implements used in this method are only two, a plough and a one-row drill. As in the several methods of sowing in rows, in this method also the rows

may be pure or may themselves consist of mixtures. In the latter case the seeds of the different kinds are mixed together in the desired proportions and sown.

In many provinces and tracts the general level of agricultural practices is somewhat high and in these regions a variety of implements for both tillage and sowing is in common use. Sowing is systematically in lines and when mixed cropping is adopted seed-drills of many kinds, some with two, some with three, four or six and one type with even twelve tynes are used, for sowing the main crops., The mixed crop is sown through a one-row drill. The exact method of sowing by which with the use of the one-row drill and one or other of the multi-row drills a definite number of rows of the main crop are made to alternate with one row of the mixed crop is very elegant in its cleverness and simplicity. At the first, second or third journey of the multi-tyned drill an appropriate hole in its hopper is plugged and behind the corresponding tyne the one-row drill is fixed and brought into operation until the one row of mixed crop is finished; in the multi-row drill the plug is now removed, the one-row drill is disconnected and the sowing of the main crop through the former with its full number of holes resumed. This alternate working and idling of the one-row drill is repeated regularly until the field is sown completely, resulting in the alternation of definite rows of the two kinds of crops with each other with great regularity.

The twelve-tyned drill of Mysore is used for sowing *ragi* and with the addition of a one-row drill eleven rows of *ragi* are sown alternating with a mixed crop generally field beans, but sometimes redgram either pure or mixed with other minor crops like the various pulses, mustard or niger, etc. With a three row--drill used with a one - row drill two rows of one crop or five rows of the same may be made to alternate with one row of the mixed crop. Drills are made with two, three, four, five and six tynes, in different parts of the country and the one with twelve tynes described above is exceptional and can be seen perhaps only in Mysore.

The sowing of the main crop is carried out by feeding the seeds through the hopper which may have one or more holes corresponding to the number of tynes or rows which the drill is to sow; these holes are usually very small and will not admit of larger seeds like groundnuts, Bengal gram or cotton being sown especially if the number of rows to be sown by the drill exceeds two or three; in these cases the holes are made larger. As an alternative and where more rows than two or three are to be sown, then a one-row drill is attached behind each of the tynes of the drill, the seed is then fed into each of these, for the hopper of these is quite large almost like a bowl and can take even large seeds like castor. In these cases the hopper of the main drill and the seed tube fixtures are removed and the drill is used only as a furrow opener.

In a great many cases instead of keeping the rows pure whether they be of the main crop or of the mixed crop, a mixture of seeds is sown in the rows themselves, so that the rows themselves have a mixed population of more than one crop. For this purpose the seeds of the different crops are mixed before sowing in the customary proportions and are then sown in rows through the drills. Such mixtures are sown

sometimes broadcast, sometimes in plough furrows by hand, sometimes drilled in rows through the multi-tynes drills or sown only through the one-row drill. In the *jowar* rows for example may be seen mixed many pulses such as blackgram, cowpeas, *matki* (*Phaseolus aconitifolius*), cucumbers, the vegetable *bhendi*, *cluster beans*, *Deccan hemp* (*Hibiscus cannabinus*), etc., in fields of cotton may be seen castor, rice, redgram, indigo, etc., in fields of *ragi* may be seen field beans, cowpeas, niger, mustard, *jowar*, Italian millet, etc.

The sowing of mixed crops is usually carried out only at the same time as the main crops, whether they are sown broadcast or in rows, in pure rows or in mixed rows. Usually there is a great difference in the period of maturity of the different crops sown, so that one crop matures and is ready for harvest long before the other. There are also cases however where all the crops come to maturity either about the same time or within a very short interval of each other. This practice necessitates a good deal of what may be called 'selective harvesting,' and is suited for careful and slow manual labour, such as only a family team can be expected to provide. The subject is further referred to under mixed cropping with reference to harvesting. Sometimes the mixed crop is sown quite a long time after the main crop. This is done when a short season crop suited only for the late season is to be sown in the midst of a long season crop sown in the early part of the season and which has to be sown in wide rows; a good example is the sowing of the horsegram in the month of September in between the rows of a standing crop of castor, sown in the month of July.

(*d*) *Transplanted mixtures.* In addition to the sowing by different methods described above the method of transplanting is also adopted in mixed cropping. This is principally the case where crops are grown under irrigation (generally under well irrigation) and where vegetable crops like brinjals, chillies, etc., are concerned. In fields of Cambodia cotton or *ragi*, many crops like onions, chillies, even a little wheat or millets are transplanted, as mixture; both in the midst of the crops and along the water channels. On the black cotton soils (Vizagapatam District) mixtures of various crops like blackgram, greengram, horsegram, cowpeas, redgram, sannhemp, etc., are sown broadcast and then plough furrows are drawn and *ragi* or *bajri* is transplanted among them.

A good deal of this kind of a combination of broadcast sowing and transplanting can be seen in the case of vegetable crops; several kinds of vegetables are sown together broadcast, and later on, even after an interval of a month or six weeks others are transplanted.

Mixed crops may be grown not only in among one another whether in rows or broadcast or transplanted but they may be grown also along the margins either on two sides of the field or all round like border crops. In such cases they usually occupy several rows in a solid strip wide or narrow according to the fancy of the grower. The safflower crop is grown in this manner as a border crop around *jowar* or wheat or other crop and then serves as a protection against stray cattle on account of its spiny nature. Redgram and castor around sugarcane fields act moreover as

windbreaks, and while grown in the midst of crops like ginger or turmeric act as shade crops. Maize is grown to a great extent along with *jowar*, in a wide strip all around the *jowar* field and so are potatoes and maize.

To a small extent crops are grown mixed by the ' strip method '. In this method instead of a row or two or one crop alternating with a few rows of the other crop, each crop takes up a wide strip of many rows, and these strips alternate with each other. Cotton and Italian millet, cotton and redgram, or with horsegram, or blackgram, *jowar* with redgram, gram or blackgram, *bajri* with redgram and *matki*, wheat with safflower and gram with safflower (Bombay) are examples of the strip method of mixed crop growing which are reported from Bombay Province. In the strips themselves the sowing is generally in rows, and through seed-drills. So far, reports show only two crops entering into the mixture by the strip method and both of them are sown pure in their respective strips.

Mixed cropping of legumes and cereals or other non-legumes

Special interest attaches to this system of cropping where a legumous crop is grown in association with a cereal crop. It is firstly a very extensively adopted form of mixed cropping in all parts of India ; secondly, it is the form of mixed cropping which has aroused attention from the beginning by its appearing to be a peculiar and interesting system of rotation, in which instead of a pure leguminous crop following a cereal in a subsequent year or season, both are grown together in the same year and repeated in the subsequent years ; thirdly, the association draws attention to the possible benefit that may accrue to the cereal on account of the well-known property possessed by leguminous crops of assimilating free nitrogen from the air through the agency of the bacteria in their root nodules. Fourthly, this aspect of mixed cropping is about the only one which has been scientifically investigated to a certain extent. In addition to all these special features are the considerations which apply to this system in common with other forms of mixed cropping where non-legumes form the crops which are grown mixed. For these reasons, this aspest of the subject is taken up first and dealt with at some length.

Perhaps the very first scientific study to be made was by Pilz[1911]and by Professor Lipman in the year 1914, subsequent to which for many years little or nothing was done on the subject. Virtanen and his associates took up the work in Helsinki (Finland) in the year 1927 after whom came a succession of many workers such as Thornton, Nicol, Nowotnowna, Wilson, Ludwig, Allison, Strong, Trumble, Gurski and Bjalfve in Europe, Willard, Benson, Lyon and others in America, Osserwarde in the Netherlands, East Indies, Calma and Tiangsong in the Philippines and M. R. Modhok in India. Some work which has not yet been published has also been done in Coimbatore India. A very detailed summary of all the work carried out until the year 1936 has been published by Nicol, *vide International Review of Agriculture*, Vol. 27—pp T 201 216 and T 241,256, and a brief statement of some of the relevant results up to 1940 has been given by M. R. Modhok (*vide Soil Sci.* Vol. 49, 1940).

The points on which conclusions have been drawn in these investigations and which will be referred to here are the following :

1. How does the legume influence the growth of the cereal ?

2. How does the legume increase the nitrogen content of the cereal ?

3. Does such increase extend to the grain and also show itself as an increase in the protein content of the grain ?

4. Does one legume differ from another in its capacity to increase the growth of the cereal ? And conversely does one cereal differ from another in its ability to take up and be benefitted by the nitrogen furnished by the roots of the legume ?

5. How does the yield of the cereal in mixed cropping compare with its yield grown pure ?

6. What exactly is the method by which the favourable action of the legume is imparted to the cereal, is it the mere decomposition of the legume roots or nodules or is there any definite product excreted by these organs, capable of being easily assimilated by the cereal roots and lastly,

7. What, if any, is the optimum proportion of legume to the cereal in the mixture ?

We must refer readers to Nicol's detailed summary for a full account of the work and conclusions on all these matters, upto the time that he wrote, and to papers by other authors for the details of their work. We shall only give a very brief extract of the conclusions.

How does the legume affect the growth of the cereal ?

Lipman gave experimental proof of the ability of some non-legumes to secure an adequate supply of nitrogen when growing together with some legumes in sand devoid of nitrogen. This however was not found to apply when the legumes concerned were cowpeas or soyabeans. In fact, as pointed out by Modhok, in 20 out of 26 cases reported Lipman did not find any beneficial action of the legume on the non-legume. Other earlier workers like Tacke, Lyon and Bizzel, however, noticed and reported the beneficial action of the legume on the non-legume. Stallings [1926] working on a mixture of wheat and soyabeans 'failed to establish any, very evident benefit derived by wheat from the legume'. Gurski [1927] found that the growing of vetches along with barley and oats led to increased yields. A great amount of work on the subject has followed since, most of which from Helsinki in Finland and Rothamstead in England. This work has led to 'less exceptionable indications that a legume, when well supplied with its proper nodule bacteria and with phosphate and potash, can obtain from the air not only sufficient nitrogen for its own needs but so much more as to satisfy the nitrogen requirements of at least one suitable non-legume plant grown beside one legume' (Nicol). The most notable positive conclusions were from the work of Virtanen and his associates, who have worked with oats and peas, with red clover and meadow foxtail, barley and peas. Working with lucerne and Italian rye grass, Nicol and Thornton found that 'given a small initial dose of nitrogenous manuring the grass when grown in association with the lucerne, contained nitrogen several times more than was supplied in the shape of manure ; also that grass grown with the lucerne even where it received no

starting dose of nitrogen contained twice as much nitrogen when grown with lucerne than when grown without lucerne '.

Field experiments however (reported by Nicol) are not very conclusive. Experiments at Rothamstead on oats—vetches are said to have suffered from rather an unfortunate choice of land. It is stated that Danish experiments in undersowing oats with legumes showed that the increase in grain ascribable to the legumes (red clover and serradella) was small over an average of years. In the 1932 experiment with oats vetches mixture (when no nitrogenous manure was applied) the yield of oats both grain and straw was higher when the crop was pure than when it was grown with vetches. In field experiments carried out by Lyon [1925] using oats and peas the conclusion is drawn that the mixture is detrimental to oats in as much as the yield of grain was always higher in the pure oat crop than in the oats—pea mixture. According to Nicol these experiments are not free from drawbacks, which may vitiate the conclusions.

A number of experiments on the effect of soyabeans and cowpeas on maize appear to show that the legumes depress yield of the maize. It should be added however that in one set of experiments (Brown in Lousiana) which were carried out over a series of five years, it was found that though in the first two years the yields of maize in the mixture were less than in the pure maize crop, in the last two years the result was the exact reverse, which may be taken to indicate that over a series of years the mixture may be favourable.

Work in the Punjab by Modhok [1940] on the association of chick pea (*Cicer arietinum*) with wheat of *senji* (*Melilotus parviflora*) with oats and of *guara* (*Cyamopsis psorialandes*) with *chari* shows that the mixing was favourable neither to the grain nor the legume. Chick pea suffered both in growth and in nitrogen content, to the extent of 35 to 40 per cent in size and 12 to 20 per cent in weight ; while the beneficial effect on the wheat was neither marked nor constant. So did *senji* in association with oats to the extent of 60 per cent in height and 80 per cent in total dry weight, with no gain on the part of the oats ; in respect of the *guara-chari* mixture however, the *chari* is definitely benefitted but there was the same depressing effect on the growth of the legume.

The depressing effect on the legume in association with a non-legume was also noticed by Virtanen, who found that in mixtures of peas with non-legumes (like barley, oats, wheat and potatoes) with increasing ratios of non-legumes to legume the growth of the peas suffers, obviously, as Virtanen remarks, from lack of nitrogen due to the fact that the non-legumes snatch away the nitrogen fixed by the legume before it could be made use of by the legume. Modhok also refers to a similar effect of the ratio of the legume to the non-legume, in their mutual action.

In an experiment with maize interplanted with the legume (*Crotalaria anagyroides*) reported by J. G. Osserwarde, Netherlands East Indies (page T. 19, *Int. Rev. of Agr.* Vol. 27, 1936) in two out of three cases the yield of maize in the combination was about the same as in the pure maize crop and in a third case was very much reduced amounting to less than about one half of the yield on the pure maize plot.

Another experiment reported is from V. C. Calma and J. P. Tiangsing and relates to the growing of a catch crop of peanuts and soyabeans along with sugarcane. The planting of the sugarcane and the sowing of the catch crops were done at the same time, and the latter were sown between the rows of sugarcane and also in the space between one set and another, the sets themselves being planted 50 cm. apart and the rows one metre apart. Both the peanuts and the soyabeans were harvested and removed when they matured. The effect of the catch crops was found to be detrimental to the sugarcane in many ways. The germination of the cane was only 75·4 per cent in the peanuts plot, 79·3 per cent in the soyabean plot, as against 88·9 per cent in the control and 93·5 per cent in the ammonium sulphate manured plot. The growth of the cane plants in the intercropped plots was stunted, the number of millable canes was also reduced and the final yield of cane also suffered seriously. The following were the yields of sugarcane in the different plots :

TABLE II

Yields of sugarcane

Plot	Yield of sugarcane
Control plot	68 tons per hectare
Pea nut plot	58·5 „ „ „
Soya beans plot	62·7 „ „ „
Ammonium sulphate manured plot	78·0 „ „ „

(*Philippine Agriculturist*, June 1940)

We shall revert to this experiment in the next heading, with reference to certain other features, but here the relevant point is that the association with legume in this particular manner was seriously harmful to the main crop of sugarcane.

Is there an increase in the nitrogen percentage of the grain or stems and leaves of the cereal in mixture than in pure cropping ? From Nicol's review of this part of the subject it would appear that the results of work on this aspect of the question have not been consistent one way or another. Westgate and Oakley found the percentage of nitrogen in wheat was slightly reduced, Lipman states that the presence of a legume does not always result in an increased proportion of nitrogen in the dry matter of the non-legume, and the former authors make the same observation. Experiments by Vatiovaara [1933] also showed a lowering of the nitrogen content in the ripe oat straw when grown in mixture with peas than when grown pure. Pilz's work [1911] with barley, maize, and oats grown pure and in mixture with legumes, showed that in the pure crops barley and maize contained a higher percentage of nitrogen than in the mixed cropping, but that in the case of the oats the contrary was the case.

In reply to a circular letter addressed to all Agricultural Chemists in India inquiring if any work on this subject had been carried out by them, the Agricultural Chemist in Coimbatore has written to say that in a field experiment conducted by him on mixed cropping using *Chitharai cholam* (Summer *cholum, Sorghum vulgare*) as the grain crop and (1) greengram (*Phaseolus radiatus*, Linn.) (2) Cluster beans (*Cyamopsis psoroloides, Dc.*) (3) red gram (*Cajanus indicus*, Spreng) and sannhemp (*Crotolaria juncea*, Linn.) as the leguminous crops, it was seen that the protein content of the grain was increased when grown in mixture with these legumes, that the average increase in protein was about 26 per cent and that the highest increase was 34 per cent which was obtained when the grain and legume were grown in equal proportion (The work has not been published yet).

In alfalfa-grass mixtures, not only do the mixtures out yield pure grass (sometimes even leaving out the alfalfa out of consideration) but the protein content of the grass is definitely higher than in the pure grown grass, viz., an average of 44 per cent for *Dactylis glomerata* and 50 per cent higher for timothy (*Nicol's review*). In reference to such mixtures the following remark by Nicol appears on the whole to be worthy of acceptance, 'provided that these (phosphate and potash) are given and that the proper nodule bacteria are present in abundance, it appears that a mixed crop is able at least to supplement the soil's nitrogen to a degree sufficient for the growth requirements of both grasses and legumes. Mixed cropping in fact seems to present us with the opportunity of gatherig nitrogen through phosphorus.

Finally, we may refer to the work of Anna Nowotnowna (*reported in Jour. Agric. Sci.* 27, 503—510) because they relate to all the experiments considered so far. These experiments relate to mixtures of the cereals and legumes, barley, rye, peas, red clover, serradella, and lucerne grown in nitrogen free (but inoculated) sand cultures. The results showed, rye grass increased in yield of total dry matter and nitrogen content in association with the legumes; thus in respect of dry matter, with peas it was three times, with clover twice, and nearly twice with serradella as compared with rye grass alone. In respect of nitrogen content, rye grass with peas contained five times, with clover three times and with serradella twice as much total nitrogen as it did in pure culture of similar age. Among the legumes, peas were found the best companion for rye and serradella came last. As regards barley, neither red clover nor lucerne had any favourable effect on the barley and only peas exerted such action in respect of dry matter, total nitrogen and nitrogen percentage.

The reason suggested as probable for the barley not benefitting by red clover and lucerne is interesting and noteworthy and deserves to be remembered in connection with cereal legume mixtures in general. The suggestion is that the period of vigorous nitrogen fixation by clover and lucerne coincided with the ripening stage of barley, when its assimilation was over and it was unable to utilise nitrogen, so that an additional factor, viz., the growth period of the crops concerned is introduced, which has to be reckoned with both in planning the experiments and interpreting the results.

How does the non legume in the mixture benefit by association with the legume? Virtanen and his associates have concluded that root nodules exude nitrogen compounds in the shape of amino-acids (which constitute almost 99 per cent); the

utilisation of these compounds by associated non-legumes may vary in degree, which may account for the fact that the benefit to the non-legume is not always the same ; that non-legumes may vary in their ability to take up or utilise these exudates, and that the legumes themselves can differ in their capacity to exude have given rise to ideas which are expressed by the very apt terms 'donors and donees of nitrogen' and that the benefit can accrue only when the donor legume is associated with the proper and appropriate donee. The terms 'compatible and incompatible' are also used, all of which are of course only descriptive and by no means explanatory. On this basis taking into consideration the large number of legumes and non-legumes among the agricultural crops of India the possible combinations to be investigated becomes almost unlimited, even allowing for the fact that agronomic considerations may restrict the number considerably.

How does the varying of the ratios of legume to non legume affect the growth of the other? In most of the work reviewed by Nicol and reported by others, observations have been made of the effect of varying the ratios between the legume and non-legume in the mixture sown. Virtanen and his associates investigated the growth of the peas and oats in the ratios of 1, 2, 2·75, 4 and 5 oat plants per pea. It was found that if the ratio of non-legume to the legume approached or exceeded 2 : 1, then the growth of both species suffered and in the above experiment the setback to peas was most evident where the cereal was numerically preponderant. Oats and vetch mixtures in three different ratios showed significant differences in yield in experiments at Rothamstead, the yield of pure oats was the highest, and went down in the mixture as the proportion of the vetches increased. Likewise in older work also (Pilz) combinations in different ratios were studied. Madhok in his experiment referred to already found that in the chick pea wheat mixture, the grain formation in the wheat seems to suffer when the ratio of chick peas to wheat is 1 : 4, and that the efficiency (relative) of the nitrogen fixation appears greatest when the ratio of chick pea to wheat is 1 : 2. We have already referred to the Coimbatore experiment where the protein content of the grain was highest when the proportion of the legume to non-legume in the mixture was 1 : 1.

Before leaving this subject, attention may be drawn to the following remark made by Nicol, as it has an important bearing upon the interpretation of all experiments on mixed cropping : 'There are evident difficulties regarding the way in which yield of single components may be compared in pure cultures and in mixture. These difficulties have been discussed at some length by Pilz [1911] ; the safest method of comparison would seem to be that used by him, whereby in a mixture of one legume and one non-legume sown at approximately equal rates, the yield of the non-legume in mixture is compared with that of the same non-legume grown in pure culture upon half the area occupied by the mixture. The basis may be said to be one of ground utilisation'. It is not known whether in all the works reviewed, the yields were calculated upon this or any other basis ; at least one was not, and in this case Nicol comes to a directly opposite conclusion to that arrived at by the author viz., Lyon in his experiment on maize - soya bean mixture. It is not unlikely

that looked at in this way other results may be capable of a different interpretation from the ones reported. In any case it is evident that in addition to the inconclusiveness of the results a new and material disturbing factor is introduced in this way which tends further to make the results far from conclusive.

Legumes and soil enrichment in nitrogen. That the growing of leguminous crops greatly enriches the soil in nitrogen by the action of the nitrogen fixing bacteria in their root nodules and that such enrichment is greatly to the benefit of the succeeding crop is perhaps too well known and too well established to require any special mention, unless it be to emphasise what is perhaps not so well known viz., that they can do so only when the soil is well provided with the other plant foods, phosphoric acid and potash, it has the necessary content of lime and that above all it is amply well stocked with the appropriate root nodule bacteria. No reference needs to be made either to the classical experiments on the subject or to the large mass of subsequent work. A measure of such increase in nitrogen is brought out in a well known Rothamstead experiment where a crop of barley following clover contained nearly twice the quantity of nitrogen that was contained in barley which followed a crop of barley. As Sir John Russell observes ' these facts are well known to the practical man and are utilised for increasing the nitrogen supply of cultivated soils and for reclaiming barren sands and clays, (*Soil Conditions and Plant Growth*, page 353). Much work has been done to determine not only the extent of the residual effect of legumes in the above manner but also the length of time that it lasts, the causes that may lead to its reduction and the ways of preventing losses, but such work has been confined to the conditions of Europe or America. As far as the tropical conditions are concerned and especially Indian conditions, similar work is a great desideratum. What is the extent of the increase in nitrogen with different or common Indian legumes ? How deep does it extend ? How does the long spell of the Indian hot weather following harvest affect the quantity, condition and location of the added store of nitrogen ? Likewise how do early rains with the help of which ploughing and other preparatory cultivation is carried out affect these ? these are all important questions which will influence the practical application of this property of legumes under Indian conditions but on which little scientific investigation has been carried out and no reliable information is therefore available.

The conclusions which may be drawn from this review of this particular aspect of mixed cropping is that the subject requires to be investigated thoroughly, both in respect of fundamentals in the laboratory and the pot culture house and as applied to field experiments, and that the scope for such work is almost unlimited. The results of the work so far are quite inconclusive ; there is as much to be said in favour of the legume—non-legume association as mixed crops, as against it ; indeed it even looks as though the results against such cropping preponderate.

Mixed cropping and soil moisture relationships

Where a particular crop has to be planted or sown in rows fairly wide apart, because the plants have a bushy habit of growth and when full grown their tops and branches will meet at some height above ground, or because their habit is that

of a bushy creeper, and when fully grown they meet and cover up the surface of the ground, is it better to grow a crop between the rows which can be harvested and removed by the time the rows close up or to keep the spaces free of crop but well stirred and worked by light hoes, or even leave them quite untouched? For instance, should cotton be grown by itself sufficiently wide apart for good growth, the space between the rows being cultivated clean or is it permissible to grow a mixed crop of say, Italian millet (as is very often the practice) in rows or coriander broadcast (as is common in some places)? Or in permanent crops like coffee, tea, rubber, or cocoanuts, should the ground between the trees or bushes be kept clean and tilled, or is it permissible to grow some crop, if it is possible to do so, for the sake of its produce or as a mere cover or green manure crop? It is true that in practice only economic considerations will decide the choice, that is to say, that practice will be adopted which yields the greatest return after deducting all expenses. Among the factors that from a scientific study can be said to influence or underlie such practices, the question of soil moisture as affected by one or other of these methods becomes a very important one. In tracts where the rainfall during the growing period is abundant or sufficient or where crops are grown under irrigation, the question is not very important but in dry cultivation and especially where the rainfall is neither ample nor certain and in the case of the *rabi* crops which are grown after the rains are almost over, all the factors which may influence the quantity of soil moisture assume importance and have to be studied. Since the bulk of mixed cropping relates to dry cultivation the methods of conserving soil moisture so as to offset the shortage or vagaries of the rainfall deserve detailed study. Is mixed cropping helpful in this respect or is it harmful? During the discussions on mixed cropping this subject was referred to by Dr Carpenter, particularly with reference to practices in tea estates; but it has even greater importance in connection with the ordinary annual field crops.

To what extent and to what depths do these inter crops like Italian millet for instance in the midst of cotton or the so-called cover crops and green manure crops deplete the soil moisture? And on the contrary to what extent do they protect the soil surface by preventing evaporation? Certain experiments in Mysore have shown that the drying effect of these crops is very great; in tests of the comparative effects of various treatments viz., soil uncultivated, soil stirred upto $1\frac{1}{2}$ inches, soil dug $1\frac{1}{2}$ feet and soil growing Bengal gram, it was found that even a small crop of Bengal gram (*Cicer arietinum*) drew upon the soil moisture to a depth of 6 feet and that this 'difference in moisture between the gram plot to a depth of 6 feet and the uncultivated plot would have been compensated for by an application of 3 inches of water over the entire plot, and between it and the plot cultivated $1\frac{1}{2}$ inches depth by an application about $5\frac{1}{2}$ inches of water. It will be necessary to conduct similar tests with other crops, so as to decide the extent of such drying effect and to what depths this may extend, with reference to the root range of the different crops. If during the growing period of the crops there is not sufficient rainfall to offset this loss of moisture it is obvious that both the main and the mixed crop would suffer. What applies to the mixed crop applies also to the moisture depleting effect of the weeds which may spring up and grow if they are not removed as they appear. All work

done so far on this subject may be taken to have established definitely such drying effect. If this should be so, then the growing of these mixed crops is detrimental; and the need is all for measures for checking such effects, either by thorough removal as in the case of weeds or other methods, which will have the effect of conserving soil moisture, by establishing soil or other mulches or by shade.

(The question of conservation of moisture by preventing surface wash, by methods to impound rain water or make the soil absorb or retain it more thoroughly and so on, all of which are essential features of dry farming are being left out of consideration, as they all relate to the period when no crop is standing on the field). The mulches are formed by either soil mulches or are provided by the thick layer of fallen leaves in estates, the leafy loppings of young branches of shade trees and plants, the prunings of tea bushes as in tea estates, or by even special materials like dry grass brought in and applied for the purpose. The soil mulch in the case of the ordinary field crops is provided by interculturing by the different kinds of bullock drawn implements or by hand tools or by both. This kind of inter-tillage stirs the surface soil to not more than two or three inches and it is a question for consideration whether such a mulch affords any protection at all and if so, whether it is large enough to justify its being carried out frequently. Mysore experiments already referred to showed that even a mulch of 1½ inches provided some protection but it was too small to be considered responsible for any increased growth (Dr Lehmann, *Annual Report of the Agricultural Chemist* in Mysore for the year 1906—1907, pp. 29, 30). This very small saving in moisture can hardly justify the importance commonly claimed for the practice and the labour required. The operation however has to be carried out, in order to get rid of the weeds and to prevent the loss of soil moisture through that cause, and in view of its importance in this respect can under no circumstances be neglected or omitted. It will be difficult to assess the value of the cultivation separately as between its soil mulch value and its weed control value. Its importance in this respect may be judged by the practice of hoeing more than once, the bullock hoeing being followed later by a hand hoeing, so that the weeds may be removed as they come up. The question whether it may be dispensed with in view of the very small saving of the soil moisture gained has no practical bearing; except perhaps to stress the fact that once weeds have been got rid of there is no further need to intercultivate even though the rows may not have closed in and interculturing may be possible. This in fact is the conclusion arrived at as the result of experiments in Rothamstead on the value of intercultivation, viz., 'the net result of all this work is to show that, provided the crop has a reasonably fair seedbed, that it is given a hoeing in its early stage and that the worst of the later weeds kept down, then any cultivation in excess of this minimum is of little direct value to the plant. In practice this minimum coincides with the number usually given.

While thus the presence of mixed crops makes it very difficult or impossible to carry out the interculture thoroughly which is so very necessary whether we look upon it as a weed control measure or a moisture conserving expedient, it has in addition been found a most serious obstacle in carrying out the ploughing of the field immediately after the main crop is harvested and before the soil begins to dry.

Such ploughing has been found to be a most beneficial dry farming practice, judged by its effect on crop yields. In experiments conducted by the Mysore Agricultural Department the value of this practice has been fully demonstrated as may be seen from the results extracted below :

TABLE III

Yield of grain ragi (Eleusine coracana) *in lb. per acre*

—	1909	1910	1911	1912	1913	1914	Average six years
Autumn ploughed	940	755	755	642	557	900	950
Ploughed shortly before sowing (in regular season)	640	445	235	315	281	375	382

(The Cultivation of *ragi* by Leslie C. Coleman page 8)

' It cannot be definitely stated whether this striking effect is due to any moisture conserving action of the ploughing ; indeed the indications are that the saving in moisture is too small to account even partially for such a large result '.

The whole conception of capillary rise of water in the soil, its rate, and the effect of a loose soil mulch as against a hardened surface has undergone change and the possibility of changes taking place as a result of the condition of the surface soil is questioned. It is perhaps even correct to believe that the hard surface soil, far from helping the sub-soil moisture to rise and be evaporated from the surface, itself forms an effective seal and prevents any such rise. In one of the numerous soil moisture determinations made by the author a curious case has come across which is worth noting in this connection. In a spot where the sub-soil water (the water table in fact) was only about 18 inches below the surface, the top soil in the hot weather was so hard and dry that the soil augur had difficulty in penetrating through it. The percentage of moisture in successive 3 inches sections of the soil proceeding from top downwards was as shown below : 3·6 per cent, 6·3 per cent, 10·6 per cent, 13·6 per cent, 14·3 per cent and 14·8 per cent at which level viz., 18 inches below ground the water table was reached. Moisture determinations were again made a month later and the results were found to be of the same order, so that even though the sub-soil was soaking wet with standing water at a depth of only 18 inches the top soil was dry and hard, (Dr A. Lehmann, *Annual report of the Agricultural Chemist in Mysore*, *vide* page 25-27, VIII). As has now been established an ' important practical consequence of the hysteresis is that the water in the soil tends to resist change, whether these are in the direction of increasing or decreasing the moisture content. Instead of moving through the pores from regions of high moisture content to low it will adapt itself to the suction gradient mainly by an alteration in the

configurations and curvature of the water films. To use an expressive Americanism, the water ' stays put ' if it can' (B. A. Keen, Physical Research and Problems of Soil Cultivation, in ' *Endeavour* ' April, 1942). The observations made by Dr Coleman in reference to the results of the experiments described above are worthy of note. He states ' the results can leave no doubt as to the immense importance of getting the land ploughed as early as possible. What factors are concerned in producing this great difference will have to remain as a subject for future investigation .'

Attention may also be drawn to the cultural practices which are adopted in the cocoanut gardens of the Mysore State which are grown in dry fields solely with a rainfall which does not exceed 25 inches in the year. It is a settled routine in these gardens to plough them six times in the year, thrice in the early rains and thrice late in the year after the rains of the year have ceased, in the belief that these are helpful in enabling the soil first to absorb as much water as possible and then to retain as much of it as possible. All permanent gardens of fruit and other trees are also invariably given a good digging after the rains are over from the month of October onwards in the same belief. If water conservation is not a factor or is not a chief factor in producing the beneficial results for which these tillage operations are adopted, then what other factors, such as bacterial action, greater aeration and weathering etc. may be responsible will have to be examined. The point to emphasise in this connection is that these forms of tillage are of undoubted benefit and that the system of mixed cropping offers in practice a serious obstacle and is therefore a hindrance in carrying them out.

We may now refer to what may be called the protective effect of the mixed crops which may be put down in favour of the system. In the first place the shade afforded by the crop whether main or mixed has been found very beneficial. On tea estates a mixed crop of *Tephrosia candida* grown as a nurse crop or as a green manure crop between the rows of the tea bushes has been of remarkable benefit in this respect. Dr Carpenter of the Toclai Research Station, writes, ' when I visited Ranchi at the end of May where and when drought conditions are very severe, tea growing in the open on clean land having a soil mulch was dying down to the soil level, whereas tea growing under the shade of a growth of *Tephrosia candida* showed vigorous growth and was not dying back. It might have been expected that the large growth of *Tephrosia candida* of the soil might have resulted in the soil becoming more depleted of moisture than land which is kept clean of extraneous plant but this did not seem to be the case as judged by the growth of the tea' (Dr Carpenter's letter to the author). In fact both in tea and coffee cultivation it is now held more or less as a general belief that (apart from the question of shade trees) it is the best to have the bushes themselves shade the ground as completely as may be consistent with the need for the free movement of the coolies and that the shade of the bushes and the mulch of the fallen leaves will conserve moisture to such an extent that forking, digging or such disturbance of the soil for the production of a soil mulch can be dispensed with. Reference may be made in this connection to the excellence of what used to be called the ' Leeming system ' of coffee growing, the distinctive feature of which was this method of shading, the ground. It is also worth noting

that the idea that tea did not require shade has now changed and shade trees are now becoming a feature in many tea estates.

In ordinary field crops also the protective effect of the crop rows whether of the main crops or of the mixed crops by shading the ground, by reducing evaporation, by breaking the velocity of the wind and the consequent rapidity of drying and by lowering the temperature near the surface of the ground, has to be noted in favour of the growing of mixed crops, as against leaving the interspaces bare of crop. Considerable work on this aspect of the subject has been done by the Agricultural Meteorologist in Poona to which reference may be made here. The temperature of the air near the ground level inside crops is much lower than in the same level in open uncropped land, the difference in the case of a sugarcane crop being very marked, viz., 14° at ground level, 5·5° at 2 feet and 3° at 3 feet height above ground. In the case of a *jowar* crop also the temperature inside the crop at ground level was much lower than in the open. There is also a tendency for the vapour pressure to decrease rapidly with height in cropped land, and the moisture content of the atmosphere inside crop is higher at all heights than in the open (R. J. Kalamkar, *Cur. Sc.* Vol. III, No. 2, August 1934, pp. 80—81). The evaporation of moisture from free water surface is found to be influenced more by the movement of the wind than by soil temperature itself; thus, upto a height of 4 feet, evaporation was found to increase with height above ground level, even during the afternoons when the ground temperature was the greatest. Wind velocity is broken and very much reduced by crops thus leading to a reduced evaporation of surface moisture inside crops. Inside a crop of *jowar*, at a height near the ground level the velocity was 35 per cent and at a height of 6 feet it was 80 per cent of the velocity out in the open uncropped land. Similarly in the case of a cotton crop at heights between 1 and 3 ft. it was cut down by 70 per cent, and in sugarcane it was 60 per cent at ground level and 90 per cent at 8 feet (P. K. Raman, *Indian J. agric. Sci.*, Vol.XIII, Part III, pp. 273 275). It is thus seen that the presence of a crop on the ground tends to conserve the moisture of the soil at and near ground level, as against leaving the ground bare which has the contrary effect. It may also be expected that a crop on the land tends to break the force of the rain and to check any rapid flow of the rain water from over the surface and thereby help the soil to absorb a greater amount of the rainfall than the bare open uncropped land. The addition of moisture during dewy nights is probably more on cropped land than in the open, on account of the larger condensation of the moisture on the plants than on the surface of the ground, though this fact is not well established. All these factors should be considered to weigh greatly in favour of a good crop cover as is implied in mixed cropping, from the point of view of conserving moisture on the surface soil.

Side by side with such conservation of moisture, there is the loss due to transpiration going on in the case of the cropped land, which draws upon and reduces the soil moisture upto varying depths at and below the root range of the crops. Root studies show a surprisingly deep root system even for crops usually considered shallow rooted. Thus wheat, oats and sugar beet send down roots upto 6 feet, barley to about 3 to 4 feet, and potatoes upto 3 feet (B. A. Keen). The depletion of soil moisture due to the presence of mixed crops should therefore extend to at least

these depths. These losses and gains to the soil moisture due to the presence of a mixed crop have therefore to be weighed against each other, and a balance struck, before we can assess the value of mixed cropping. One other factor to be considered with reference to this aspect of the subject, is the extent in width and depth of the root range of the crops employed in mixed cropping. If both the main and the mixed crop have the same depth and area of feeding roots, the effect of the mixed crop cannot but be detrimental to the main crop, other things being equal. On the other hand, if the range of the feeding roots of the one crop is much deeper than that of the other then they may be more compatible, and the harm to either may not be great. Root studies of some important crops have been in progress in India to some extent, for elucidating many factors of crop production, and it will be very desirable that the studies should relate to more crops and with reference to the problem of mixed cropping, so that we may have more knowledge as to what mixtures are suitable and what are not. This as a matter of fact forms part of the recommendations made at the conferencce. The subject of root depth in relation to the uptake of plant foods from the soil is dealt with in a separate section.

Mixed cropping and nitrification

It is sometimes claimed in favour of mixed cropping and the shade and humidity referred to above, that under these conditions nitrification proceeds more rapidly. Thus Dr J. A. Voelcer says ' It is known also that the process of nitrification in soils is much more active when a growing crop is on the ground than when the latter lies fallow ' (*Improvement of Indian Agriculture*, page 234). Later work does not lend any support to this view. While it is true that bacterial activity is greater in cropped land than in the fallow, it appears to be fairly well-established that such activity does not relate to nitrification. On the other hand it has been found that ' the total amount of nitrate present in cropped soils is less than that in adjoining fallow soils even when allowance is made for the quantity absorbed by the plant. This fact has been observed at Rothamstead, at Grignon, at Ithaca, in Europe, India and Egypt '. (Sir John Russell, *Soil Conditions and Plant Growth*, page 509) Indeed it has been suggested that some crops interfere with nitrate accumulation. ' It is thus seen that the view that mixed cropping is favourable to nitrification is not correct. Work on the nitrogen fixation Capacity of black cotton soils in the Central Provinces also brings out the fact that the Capacity 5 higher in fallow soil than in similer soil taken from adjoining cropped fields (D. V. Pal, *Proc. Nat. Inst. of Sc. Ind.* Vol. III, No. 2).

MIXED CROPPING IN RELATION TO THE UTILISATION OF PLANT FOODS

It may be claimed in favour of mixed cropping that under this system the resources of the soil in regard to plant foods naturally present in it or added in the shape of manure are utilised to a fuller extent than will be the case when only a single crop is grown. This result may follow from the facts (1) that the roots of the different crops are of varying depths, such as those of shallow rooted crops and of deep rooted crops and (2) crops vary in the quantities of the different plant foods required or removed by them from the soil. That deep rooted crops can take up plant foods from greater depths as their roots traverse and can forage in the deeper layers of the soil is almost self-evident. Experimental proof is however available

in one of the early experiments in agricultural research, viz., one by Eckenbrecher quoted by Storer. Eckenbrecher arranged an experiment with oats and lupines in such a manner that nitrogen in the form of nitrates could be available or accessible to the roots only at a great depth and not near the surface. The oats in the experiment made only a poor growth, as the roots were confined to the layer of the soil near the top but the lupines made a vigorous growth and their roots had reached down to the layer where the nitrate was buried, (*Storer's Chemistry as applied to Agriculture*, Vol. III, page 54). As the mixture of crops usually found in mixed cropping consists generally of a shallow rooted crop such as a cereal grain like rice, *ragi*, *jowar*, Italian millets, etc., with a deep rooted crop like redgram, cotton, field beans, etc., both the upper and the lower deeper layers of the soil are drawn upon by the crops and utilised in the crop season. From this point of view it is necessary or advisable that the crops selected for mixed cropping should consist of these two different types and not plants of only one type, such as either shallow rooted crops alone or deep rooted crops alone. There is no definite information available regarding the depths which are usually traversed by the different field crops in India, in the different principal soil types, such as the light Gangetic alluvium, the black cotton soils, and the red (lateritic) type of soil of South India. Great and striking differences are likely to exist in these different soils and in respect of the different crops the depths considered usual in one type may be far exceeded in others. During a visit to the Sugarcane Research Station at Shahjahanpur by the author it was seen that a cane clump whose root depth was being examined had a root depth which was very much more than anything seen in the soils of Mysore. There can be no doubt that the depths attained in this (Shahjahanpur) type of soils by the different crops will be found to be greater than on South Indian soils, and perhaps in the black cotton soils. In the latter too the fact that these soils vary very much in depth and are underlaid by rocks in varying degrees of disintegration or hardness at different depths below the soil may cause further differences in the root depths of crops. In one and the same type of soil however the depths of roots relatively to each other are likely to be the same as in another type and their comparative rank or position may not be affected.

Reference may be made to the studies of the depths of roots in the various new varieties of sugarcane at the Imperial Sugarcane Research Station at Coimbatore. These reveal very striking differences in the depth, number and manner of develop, ment of the roots and these have been found to correspond to important differences in the robustness of growth of the particular varieties as compared with one another. As a result of such differences the varieties presumably differ in the amount of water and plant food they are able to take from the soil. It is greatly to be desired that both from this point of view and from the point of view of the utilisation of soil moisture, studies of the root depths should be systematically undertaken for all the principal field crops and in the three different soil tracts.

Root studies are also desirable in respect of irrigated cultivation, (especially in the Punjab where much mixed cropping is practised under irrigated cultivation) as there is no doubt that under this condition material differenecs may be brought about in the depth and range of the roots. Such differences may arise even under

normal irrigation and soils, but under conditions of a high water table and of salt accumulation and so on, which frequently accompany irrigation in a flat country difficult of drainage, unexpected differences are likely to be found in the character of the root system.

A fuller utilisation of the plant food resources is also made possible because crops seem to possess inherent peculiarities in taking up some plant food elements more largely than others although this is by no means an indication of what they will respond to most when applied as manure Crops differ not only in the quantities of plant foods each of them remove but also in the proportion in which these are taken. There is no doubt that crops do exercise some kind of selective action in regard to these plant food elements or differ in their 'feeding powers' as it is sometimes termed. As far as can be seen, no figures seem to have been worked out for the total quantities of the different plant foods which are removed from the soil by the above ground parts (including leaves, stems, straw, grain, chaff, pods, husks, etc.) of the field crops of India, under average cropping conditions except in a very few cases. As such figures are however available for European and American crops these are extracted in Table IV in order to bring out the extent of such differences.

TABLE IV

Total quantities of plant foods removed by some important crops and the proportion in which they are removed

Serial number	Crop	P_2O_5 Quantity	Ratio	K_2O Quantity	Ratio	N Quantity	Ratio
1	Wheat	21	43	29	60	48	100
2	Barley	21	43	36	75	48	100
3	Oats	20	36	46	83	55	100
4	Beans	29	27	17	63	106	100
5	Potatoes	24	35	77	115	67	100

(Worked out in lb., per acre for a 30 bushel, 40 bushel, 45 bushel and 30 bushel crop of wheat, barley, oats and beans respectively, and for a 6 ton crop of potatoes, from Warington's figures given in *Soil Conditions and Plant Growth*, by Sir John Russell, page 507, sixth edition).

Taking the nitrogen as 100, it will be seen that the phosphoric acid varies from 27 to 43, the potash from 60 to 115 and the nitrogen itself from 48 to 106, as between the different crops. It is surmised that the secretions from roots or root sap differ in character from crop to crop and that some are able to dissolve out more phosphates than others, although what this acid may be whether merely carbonic or something more effective may be said to be not quite decided.

From practical experience relating to the response of different crops to various manures the theory of ' dominant ingredients ' attributed to Ville draws attention to the same differential action exercised by crops in making use of plant foods in the soil or in the manure, whatever may be the mechanism by which such differences may be brought about. Under this classification (referring again to European crops) the cereals except maize come in the class for which nitrogen is the dominant constituent and the leguminous crops, potatoes and flax have potash as the dominant constituent. As for Indian crops, no such predeliction is noticeable, as the general experience with manuring shows that for nearly all the crops nitrogen is the most important and the most predominantly needed plant food, the others coming a long way behind, and often leading to no increase at all.

Reference may be made to the fact that the plant food elements are not at all made use of at the same time, but are taken up mainly or in large quantities at particular stages, in the growth of the crop and that this period in the growth is also different for different crops. An abundance of one or other of these plant foods at particular stages in the growth of the crop also appears to be favourable in particular respects. Nitrogen is taken up largely from the very outset by all crops. Nitrogen specially applied about the middle of the growing period in the case of the grain crops has been claimed to favour the increase of the protein content of the grain.

In regard to sugarcane a fact of some interest in this connection may be mentioned. It has been the general experience in India that although the sugarcane crop removes from the soil surprisingly large quantities of potash, there is little or no response to potash manuring ; on the other hand there have been experiments in which potash has resulted in a reduction in the yield. In all these cases the potash manure has been applied like any other manure at the early stages of the growth, say up to a period of three or four months, after which it is not usual to apply manures to the cane. At the Shahjahanpur Sugarcane Station the author was given to understand that the absorption of potash by sugarcane takes place largely in the later stages of the growth. Apart from showing that plants take up plant foods more largely at certain stages than at others, this fact affords a possible explanation of the observed results of potash manuring and a promising suggestion as to the lines both of future manurial experiments with potash for sugarcane and perhaps even for immediate practical application. The point however to be stressed in connection with the utilisation of plant foods is that crops may differ in the stages in which they may take up the plant foods as they do in respect of the quantities and proportions. It will be a very desirable line of research to determine for the main crops the particular periods of growth during which the maximum absorption of nitrogen, phosphoric acid and potash each takes place.

These three considerations viz., the difference in the depths of the roots of different crops, in their capacity of selective absorption of plant foods and in the growth period when maximum absorption takes place would appear to make mixed cropping a more efficient and balanced utilisation of the manurial resources of the soil in any particular crop season than the growing of single crops with or without rotation.

Mixed cropping as a method of insurance against loss

It is as a method of insurance against total crop failures that the system of mixed cropping finds its merit and justification in the opinion of all observers. Thus Dr Buchanan as long ago as a century and half writes ' the reason for sowing these plants (*Dolichos lab-lab* and *Cajanus indicus*) along with *ragi* (*Eleusine coracana*) seems to be, that the rains frequently fail and then the *ragi* dies altogether or at least the crop is very scanty ; but in that case the leguminous plants resist the drought and are ripened by the dews which are strong in the autumn. When the *ragi* succeeds, the leguminous plants are oppressed by it and produce only the small return mentioned in the above list, but when the *ragi* fails they spread wonderfully and give a very considerable return, '(Dr Buchanan's *Travels in Mysore*, Vol. 1, page 101). R. G. Allen writes 'an examination of the fields will show that most sowings are mixed, partly to get the necessary variety, and partly it is true as a species of insurance against unfavourable weather conditions and as a method of providing the effects of crop rotation,' Allen R.G., *An Outline of Indian Agriculture*, page 25). 'Mixed cropping was based mainly on economic considerations. In the United Provinces it was an insurance against the inclemencies of the weather, pests and diseases'—Dr B. L. Sethi. 'Villagers would not give up the practice, as they were certain of getting good yields from one or other according to seasonal fluctuations',—Mr. S. Harachand Singh. ' It is generally accepted that mixed cropping is an insurance and also maintains soil fertility',—Dr B. N. Singh. 'Mixed cropping in Mysore has been practised as an insurance against the vagaries of nature and the precariousness of the rains', Director of Agriculture, Mysore. ' Mixed cropping as an insurance against bad weather and soil conditions is practised ', Director of Agriculture, Bhopal. ' The practice is adopted primarily to secure at least a small return under conditions in which pure sown crops would be total failures, in other words as an insurance against total failure of crops sown pure', Director of Agriculture, Madras. It was this feature of mixed cropping which accounts for the result described by one of the witnesses before the Royal Commsision on Agriculture (Rao Bahadur Govind Bhai Naib Dewan, Baroda). ' Some effort at separating the mixtures and making suitable rotations out of them was made but without any striking results of any importance '. Whether the system was designed deliberately with this aim in view or that it happens to serve this purpose among other advantages, there is no doubt that in the peculiar conditions of Indian agriculture, depending as it does very largely upon a rainfall the uncertainties of which are the only certainties in the country, this aspect of mixed cropping must be considered to be the most important. The need and the importance of this kind of insurance far outweighs the importance that may otherwise be attached to well established principles like crop rotations, keeping varieties pure, getting the maximum from every crop and so on, to all of which the system may in many respects be regarded as diametrically opposed. When it is remembered further that mixed cropping is adopted almost entirely only in the case of dryland crops which depend solely on the rains, as distinguished from irrigated crops, the need for such a form of insurance becomes even more evident.

We may now deal with some of the crop mixtures which illustrate this aspect of the system. The most important illustration which

is also perhaps the most general one seen throughout India is the mixing of the red gram crop with the grain crops usually grown in the respective tracts. In Mysore and many parts of Madras,with the food grain *ragi*, the *ragi* fieldbean mixture is another important illustration. Cotton with a grain crop, castor with a grain crop, castor with horsegram, the various *bajra* mixtures with groundnuts, pulses and oil seeds, in fact most of the large number of mixtures described in these pages, all illustrate this aspect of mixed cropping. In fact whenever two crops of different periods of maturity comprise the mixture, which applies to the largest number of mixed crops, this aspect may be said to be illustrated. Even with crops of the same duration, like wheat and gram, wheat and linseed, wheat and mustard, etc., differences in their ability to make use of soil moisture at different depths and of the heavy dews of the season help this insurance against loss.

While all these refer to the mixture of totally different crops, the case of the mixed crops where the mixture comprises different varieties, strains or species of the same crop, comes in a different class but illustrates the same principle. Separate reference has to be made to this special type of mixed cropping in which there is only one particular crop grown but in which the mixture arises from the fact that two or more varieties of it are grown together, the seeds being mixed and sown. The question has an important bearing upon the practical value and application of the vast amount of work in progress in the isolation, testing, multiplication of improved varieties and strains and the recommendation that these should be grown pure in preference to a promiscuous mixture of strains and varieties. The object in growing only pure strains relates both to the quality and the quantity or yield of the produce and also to the need and advantage from a commercial point of view of a single pure type of the produce. The importance of purity in varieties which possess marked differentiating characters, such as the most obvious one of colour or others less striking to the eye but equally marked like cooking quality, malting quality, suitability for different purposes, etc., or spinning quality in cotton, oil content etc., hardly needs to be pointed out; but the matter concerns in addition the growing of mixed strains in the same variety, where the question of quality does not arise. In the former case one would expect that under no circumstances can a mixture be justified or approved. Instances are however reported which show that such mixtures are not only prevelant but are also found advantageous and that therefore there is something to be said in their favour, which may justify approval of the practice if not a recommendation for their extension. It is the experience in Mysore that the growing of two or more strains or varieties of *ragi* in preference to a single pure strain or variety even if the latter is a high yield in special selection, like the H-40, or H-22 proves better under certain special circumstances than growing the pure strain. The H-22 requires a higher rainfall specially towards the end of the year, this condition obtains only in the Eastern districts generally, whereas the H-40 is not so, with the result that if a mixture is sown as ryots very often do, then a good crop is obtained, whether the rains are early or late. According to the tract and its rainfall, it happens that either the one or the other or a mixture of both scores. In fact the ryots' disinclination to sow pure crop strains is generally based upon the belief that over a long series of years a

mixture is found safer than pure one. Even in parts of England ' increased yield from a mixture of varieties is stoutly alleged by advocates of the practice' (F. C. Engledow and Ramiah). It may be recalled also that in the early years of wheat improvement in England by Prof Biffen a rather spirited controversy went on regarding the merits of a pure strain as against the sowing of mixed strains, the superiority of the latter being advocated by Dr William Saunders of the Canadian Department of Agriculture (apparently for the conditions of his province).

Some support is lent to the apparent superiority of mixtures over pure crops in certain experiments by Engledow and Ramiah (reported in *Jour. Agria. Sci.*, Vol. XX, 1930). In this paper the somewhat novel idea is mooted that such mixing leads to intensive competition under the stress of which both development and yield are favoured. Mr Ramiah writes to say that end rows in varietal test plots show a marked increase in development over those inside the plot and that such development cannot be put down to the larger amount of space which these rows enjoy. If this important finding should prove quite correct and generally applicable then a very strong case may be said to be made out in favour of mixing crops. The subject has such an important bearing upon the work of plant improvement and recommendations for the sowing of improved varieties that it deserves to be investigated further.

The most interesting example of this kind is the growing together of two distinct species of cotton, viz., *G. hirsutum* and *G. herbaceum* in mixture, contrary to the emphasis that has always been laid on the growing of cotton pure and quite contrary even to the legislative enactments like the Cotton Transport Act and the Cotton Ginning and Pressing Act all of which are aimed at the prevention of mixtures. It is reported that in the Punjab both local *G. hirsutum* cotton and American Cotton are grown together and that this yields a better crop than pure crops of one or the other. It is not stated whether the cotton of the two varieties is picked separately or together. It is reported from Indore (K. Ramiah) that the practice in the Indore plateau is to grow likewise a mixture of these cottons, that they are both picked together and sold by growers and that in the gins and godowns of the dealers the two are separated, and sorted out from the mixed *kappas*. It should certainly cost a fair amount of money to effect such sorting and the merchant will no doubt pass it on to the grower, who must therefore be obtaining a lower price for the mixture than for pure *kappas*. It is reported that the yield of the cotton from the mixture is greater than from a pure crop of either and further more that losses due to seasonal conditions are largely avoided. Other advantages are also noted viz., that the mixed cotton is of a higher quality, that the incidence of disease is less and so on. But it is not difficult to realise that what really decides the cultivators' preference for the mixture is this particular insurance against loss, which so successfully dodges the drought.

As against these observations, attention may be drawn to certain experiments in Mysore, in which the results of sowing pure strains of *ragi* were compared with those of sowing mixed strains. These experiments relate to three strains of pure

ragi, and were carried out over a period of two years. The results are shown in Table V.

TABLE V

Yield of grain in lb. per acre

Type	1914		1915	
	Pure	Mixed	Pure	Mixed
1	2485	1941	1093	583
2	2220	1690	1125	1083
3	2160	1536	1750	1210

With reference to the above results, Dr Coleman remarks ' The belief is fairly common in Mysore that mixtures are grown because the cultivator has found them to yield more than any of the pure types if grown separately. The few experiments we have carried out do not in any way support this view. In fact the pure types have, in cases experimented upon, give a higher yield than the original mixtures from which they were isolated, and in some cases the differences have been very marked '. It is of course arguable that the experiments relate to only two years, whereas the ryots' belief is based upon the experience of many years.

The insurance against pests and diseases when crops or varieties are sown mixed is also an important aspect, especially when we remember that the pests and diseases are so many and so destructive and that satisfactory remedial measures are so few. The insurance afforded by mixtures in respect of wilts and rusts especially is worthy of special notice. As regards insect pests perhaps the best illustration is the castor semi-looper pest which defoliates the crop so badly, leaving only bare stems that field has to be ploughed up and sown to another crop if the season would permit it. A mixed crop of horsegram or groundnuts when grown as a mixture in between castor rows as is often done, serves as an effective insurance, as they yield a crop and a money return although the castor may be a complete failure. This subject is dealt with in the next heading.

A case of mixed planting of two varieties of sugarcane with the object apparently of affording mutual protection is reported from the Argentine where the experimental interplanting related to the varieties POJ 213 and POJ 36. (*International Sugar Journal*, Vol. 37, 1933.) The following summary of this experiment has been kindly furnished by Mr Nanda Lal Dutta, Government Sugarcane Expert, Coimbatore. ' In Argentine POJ 213 which lodges very badly and POJ 36 which has an erect habit were mixed and planted in alternate rows and also in the same row. When planted in alternate rows POJ 213 lodged and POJ 36 always gave larger yields. In the mixed plantings which were continued to the sixth ratoon crop the two varieties existed together without either tending to gain ascendency over the other, either in number or weight of stalks or sugar content'.

MIXED CROPPING IN RELATION TO INSECT PESTS AND DISEASES

Both in respect of insect pests and fungus and other plant diseases their incidence and spread are held to be greatly promoted by the removal of the mixed natural vegetation in any region and its replacement by large stretches of single crops, as is brought about in the cultivation of field crops or by large plantations. The mixing of crops so common in India, says Dr Butler, 'has its advantages from this point of view, for a field of say, wheat, barley, gram, linseed and peas mingled together will probably suffer less from parasites than five separate plots of these plants', (*Fungi and Plant diseases*, page 107). It seems quite reasonable to suppose that if one or more rows of a crop which are not attacked by a particular disease or pest are interposed as a mixed crop in among another which is subject to attacks by that pest or disease then it can to some extent prevent the spread of the pest or disease across the field and thereby keep it in check and reduce the damage. This kind of beneficial effect can of course be secured only if the mixed crop is of such a kind that it is not susceptible to the particular pest or disease; in other words it will apply only in the case of particular combinations and not others. To what extent therefore this advantage may be expected in respect of the commonly practised mixtures and with reference to what particular pests or diseases is a point of great practical importance. It is also possible that some crops may have a repellent effect upon certain pests, which may therefore be grown as a mixed or a border crop to keep out the pest from the main crop which may otherwise be attacked and damaged. It is not known if there are any such among the ordinary crops and to what extent they can act as a protective crop. Bitter leaved plants, or those with strong smells like fenugreek and coriander respectively are sometimes mentioned by kitchen gardeners but it is doubtful if there is any truth in the belief. In any case, the belief does exist and it may be useful to obtain more information on this interesting subject.

It is also believed that some crops serve as a 'Trap crops', which will draw the attack to themselves and thereby protect the main crop from the attack by the same pest. The crop *bhendi* (*Hibiscus esculentis*) in the midst of cotton is reputed to possess this quality with reference to the cotton boll weevil, and its use as a mixed crop in cotton was at one time recommended for this reason. It is now found however to be quite useless and indeed according to Dr K. A. Rahman, to be harmful because it increases the damage rather than reducing it. Furthermore it mainly attracts only one species of boll worm viz., *Erias fabias* out of the three Erias. In regard to the supposed use of a windbreak or border crop of sugarcane to reduce damage by the white fly, Dr Rahman says that the border crop of cotton near sugarcane was vastly more attacked and so the sugarcane border did not check the white fly Dr Rahman also found 'jantar' (*Sesbania* spp.) useless in this respect, when grown as a windbreak around cotton.

It is stated that the borer pests (*Sesamia inferens*) and (*Chilo zonallus*) and *simplex*, are pests on both sugarcane and maize and *jowar* but it is major pest on the latter and a very minor one on the sugarcane. The growing of maize and *jowar* as short season crops in among or around sugarcane can attract only those borers

and not the *Diatroea* spp. which is the borer mainly responsible for the 'dead hearts' in sugarcane. (*Vide* Final Report by K. A. Rahman on *The Punjab Pink Spotted Bollworm Scheme and Annual Report for 1941*). In the case of the *jowar* earhead fly (*Calocoris angustatus* L.) a certain amount of reduction of the spread may be secured by the growing of redgram as a mixed crop (which is a common practice in case some two or three rows of this crop should alternate with the *jowar* in the manner of 'strip' cropping. In fact the author does not remember to have seen this fly pest to any great extent in *jowar* growing tracts where mixed cropping with redgram is largely practised. What other observers may have noticed it will be interesting to know. Two of the worst pests of dry land food crops in Mysore viz., the Deccan grasshopper and the hairy caterpillar (*Amsacta albistriga*) attack not only the *jowar* and *ragi* but also all the usual mixed crops, viz., young redgram young field beans, and other pulse crops and so on. Although the fact that both main crops and mixed crops form hosts to the pests and this may be tantamount to sowing a single crop as far as facility for spreading is concerned, it is also possible to regard it as a protection or atleast a factor tending to reduce the pest to that extent on the main crop. It is as a matter of fact so regarded by many cultivators.

Likewise the ' plume moth pod borer ' of field bean which is a bad pest on this crop equally attacks the red gram pods, and this circumstance may in the case of mixtures be looked upon as an ameliorating factor. The same remark applies to the stinking bug (*Coptosoma*) which is common to the above two crops.

In the case of the eel-worm, *Heterodera marioni*, an interesting instance of the use of the tomato crop as a 'trap crop ' is mentioned. On a small scale it was found that tomato plants withdrew 98 per cent of eel-worms in a single planting and that cowpeas withdrew up to 30 per cent. Total eradication of eel-worms was however not possible as even after 16 plantings the pest was not completely removed. It however forms a good example of a trap crop, (Phytopathology XXIV 6, 635—658, *Godfrey & Hoshino and Godfrey & Hagan*). Sometimes the date palms (*Dactylis sylvestris*) is considered as a trap crop for the cocoanut beetle (*Oryctus rhinoceros*) and is believed to attract the beetle away from the cocoanut trees to themselves and thus to protect the cocoanut trees. Likewise bushes of *Euphorbia tirucalli* and clumps of plantain trees are considered as repellents for this beetle and are for this reason often planted around cocoanut plants especially the young ones. Many of these beliefs have not been tested in a systematic manner to find out to what extent they are correct.

As a protection though not against insects but against the larger animals like stray cattle, jackals, wild pigs, etc., a certain amount of crop mixture is resorted to. The most familiar example is the growing of safflower as a border crop all round the main crops like Bengal gram, wheat, or *rabi jowar*. As the safflower is a spiny crop cattle do not touch it nor cross over to the main crop which they can eat. Some varieties of sugarcane which are soft rinded and are subject to a lot of damage by jackals and wild pigs are like the *pattapatti* (striped) cane of Mysore very superior in yield and quality. On account of this risk of damage by these animals, such canes cannot be grown at all in certain tracts. In order to get over this difficulty

the practice prevails in such tracts to plant a hard rinded cane like the *cheni* or the *marakabbu* all round the field and plant the *pattapatti* inside this protective belt. In addition sets may be planted here and there in the interior also along with the *pattapatti*, almost in the nature of a mixed crop.

It is also possible that in the case of insects attacking the roots of plants, such as the wire worms, and various cockchafer grubs and mealy bugs and so on, an immune crop interposed as a mixed crop may intercept the free movement of the pest from row to row of the susceptible crop and thereby afford protection to the main crop to a certain extent.

On the other hand far from acting as a beneficial agent a mixed crop may prove positively helpful to the spread of pests in certain cases. This is due to the fact that fields with mixed crops do not admit of the thorough interculture which may be necessary to stir up the soil in certain stages and destroy the pupae or expose their hiding ground. When crops are grown in rows far apart or chess board fashion, it is possible to harrow with bullock implements like the bladed harrows thoroughly between the rows and in the second case both along and across. A case in point relates to the castor semi-looper insect pest which is very destructive to the castor as it defoliates the crop seriously. Pupation takes place both on the dry leaves on the plant and also in the ground below, and if a good harrowing can be given, many pupae may be destroyed ; but the presence of an inter-crop like horsegram or ground nuts, which are both common makes this harrowing impossible, thereby helping the emergence of another brood in the crop season itself. The late Dr Kunhi Kannan, Entomologist in Mysore who studied the pest closely used to complain of this parctice as a serious hindrance in controlling this pest. It must however be mentioned that even in mixed cropping, where sowing is in rows, these are sufficiently wide apart for one or two hoeings with interculturing implements with hoepoints and with bladed harrows with blades about six or nine inches in length. The above instance must therefore be considered rather exceptional although from the point of view of plant sanitation through clean cultivation, this particular aspect of facility for interculture cannot be underestimated.

The shade provided by shade trees in coffee estates is inimical to the spread of the coffee stem borer beetle pest (*Xylotricus quadripis*, Ch.) or rather, the light let in when shade trees are removed or which is a feature of estates with insufficient shade, is very favourable to the spread of the pest. Whether the shade or the shutting in of light which results from the presence of mixed crops in between the rows of a main crop has a similar restraining effect on any pests of field crops and if so, what they may exactly be is a matter for special observation.

Some shade trees have the reverse effect in certain cases when they form alternate hosts to the pests of the cultivated crop and thereby perpetuate the pest and render control measure ineffectual. The 'shot hole borer' which attacks the branches of robusta coffee is also present on the *Erythrina* trees which form the temporary shade or nurse trees in such plantations. The troublesome leaf eating caterpillar (*Eupterote*

canaraica M.) on cardamoms takes shelter in the shade trees and makes control measures difficult.

The interaction of one crop with another as good or bad from this point of view of pest and disease control deserves greater study and in respect of at least the common mixed crops, or in the words of Dr K. A. Rahman ' in all cases of mixed cropping, the entomological aspect should receive adequate attention to avert both disappointment and disaster.'

Plant diseases

The above observations in regard to mixed cropping with reference to insect pests apply more or less to plant diseases also, *mutatis mutandis*. An immune crop or variety of the same crop interposed in rows or broadcast in among a susceptible crop or variety not only breaks or checks the progress of a disease but also reduces the loss from the cultivation to an extent proportional to the ratio of the immune mixture. This may be seen strikingly in the case of coffee (arabica) where in the midst of ordinary arabica badly attacked with red leaf disease and almost with bare branches may be seen many bushes said to be hybrid or other strains (like Kents for example) which stand out conspicuously with a good leaf cover, the contrast being very striking indeed. All resistant types of different crops afford a similar example. The immune crop or variety yields a crop and thus serves an insurance against total or very great loss which may otherwise result. Of course such varieties can be used in mixtures only if they are suitable in other respects also.

A mixed crop of low growing habit in between a crop with a taller habit has been found to exercise a palliative action against diseases to which the latter may be subject, from the fact that the intercrop reduces the soil temperature near the surface of the ground and thereby makes the soil less favourable to the development of certain fungi. Thus the growing of a mixed crop of *P. aconitifolius* with cotton resulted in a reduction in the mortality of the cotton plants due to root rot and had thus a protective effect. It was noteworthy that the disease became more evident when the ground was insufficiently covered by the mixed crop, as during the first fortnight of the growth or where the growth was patchy, thereby connecting the presence of the mixed crop and the checking of the disease as cause and effect. It is however stated that this beneficial action was seen to be greater in the case of American cotton than in *deshi* cotton so that the need is made out for a study of the mutual reactions of crops in this regard also. R. S. Vasudeva reports similar protective action exercised by a crop of *jowar* in between cotton, which shows that the shade is the principal factor whether provided by a low growing or tall growing crop. Experiments in Indore (reported by K. Ramiah) reveal some striking results in growing cotton of two distinct species like the *hirsutum* (American) and *deshi* (arboreum) in mixture. The practice is said to be general among cultivators and the results of experiments indicate among other important facts.

(1). The incidence of red leaf and leaf roll to which the American cotton is very much subject is distinctly less in the American cotton grown in association with

deshi than in the pure American cotton grown. (2). The *deshi*, component, which is susceptible to the fusarium wilt present in the soil, gets some protection from the disease, particularly in the early stages, when grown in association with the American which is immune to the disease. (3). The final yields of the mixture were either equal to or even greater than those of the pure types according to the season.

The mixture thus proves as far as disease is concerned, advantageous to both the components of the mixture, each protecting the other against the particular disease to which they are severally subject. It will be most interesting and useful to know whether in the many combinations described in this article there are any which may exert such a markedly beneficial action mutually upon each other in respect of disease control in the same manner as the above instance.

Whether the reduction of temperature and the increase in humidity near the surface of the soil brought about by a low growing mixed crop, can always be considered to be beneficial in this way may perhaps be doubted, as the same factors may exert a favourable effect on other fungi both above ground and below ground, such as the different mildews, damping off fungi and others which generally spread with greater ease in a moist atmosphere. That so much shade is very favourable to the spread of disease is instanced by the Pink disease (*Corticum salmonicolour*) of rubber, which is favoured by shade and which is checked when the shade is reduced. Other instances where the presence of a mixed crop is likely to prove favourable to the spread of disease may also be pointed out. Thus when there exist as mixtures either in the shape of deliberately mixed field crops or in the shape of natural mixed vegetation, plants which are hosts to any main or other crop, then this mixture proves a great hindrance in controlling the disease, and helps in both spreading and perpetuating it. The ' oideums ' of several species which attack plants of the cruciferous order very largely find in a mixed crop of plants belonging to the order, such as turnips mustard, rape, or the vegetable crops radish, cabbage, etc., or the weeds of that order a favourable factor in spreading over the whole field. In the case of the ' Kole roga ' of arecanuts (*Phytophthora areca*) it has been found that the presence of sandal trees in or about the garden or of plants *Coloccasia* spp. is helpful in perpetuating the disease as they help in the propagation of the disease, by furnishing one of the elements necessary in spore formation.

A similar mixture in which one crop acts as a favourable factor in spreading or perpetuating a disease to which another crop in mixture with it, is when solanaceous crops like potatoes, chillies, brinjals tomatoes, etc., are grown together or when weeds belonging to this order infest the field. The bacterial wilt disease (called 'ring disease' in the case of the potato) attacks all these crops and mixtures and even rotations of these have to be avoided.

As other examples may be mentioned, Hypochnus (*Corticium solani*) attacking plants of even different orders such as potato, tomato, cowpeas, groundnut, and Trichosanthes ; mildew (*Oidiopsis taurica*, Lev. *Erysiphe taurica*) attacking chillies, brinjals, *guar*, fenugreek, garlic, fennel ; white rust (*Cystopus candidus*) attacking a number of cruciferous crops, and weeds, the downy mildew (*Perenospora parasitaica*) the *Erysiphe cichoracearum* on *bhendi*, and on many cucurbitaceous plants.

In the case of certain root diseases of rubber caused by species of *Fomes* and *Poria hypobrunnea*, it has been found that some of the crops used as green manures viz., *Crotolaria anagyroides* and *Teprosia vogelli* are very susceptible to the same disease and under normal circumstances have to be avoided. Curiously enough this very property of these crops is taken advantage of for the purpose of locating the rubber trees the roots of which may have been attacked and which have to be removed and burnt, so as to protect the healthy trees from infection. If these crops are grown throughout the estate, then, wherever diseased rubber trees are present, these green manure crops become infected and diseased patches show up conspicuously and help to locate diseased rubber. They serve as 'indicators', so that the rubber trees around these centres of diseased green manure plants alone can be uprooted and destroyed, and the spreading of the infection of other rubber trees checked.

The clean tillage of the soil, and the removal and burning of weed and other unwanted vegetation which are important measures of disease control and plant sanitation considerably militate against the system of mixed crops or vegetation and only a close study of the interaction of crops on each other in this respect can reveal what the safe combinations may be or to what extent the advantages can be balanced against the harmful effects and the system can be profitably adopted. On the whole, it may be said that as long as mixtures of the kind referred to above are avoided, the system of mixed cropping may be considered more helpful rather than otherwise in respect of the prevention of the spread of disease.

Reference may be made to the theory of the exudation by the roots of certain plants of poisons, which prove harmful to plants grown in association or nearby. Grass growing in apple orchards has been found to exert such poisonous action on the apple trees. Many causes other than the exudation of poisons by the grass roots have been discussed and examined, and it seems to be established now that the injurious effect of the grass is really due to some poisonous exudation (*Soil Conditions* and *Plant Growth*, by Sir John Russell, page 502). Under certain conditions a similar injurious action is exerted by the grass Cynodon dactylon on cotton; the effect of the grass is unmistakable and the spread of the grass directly leads to a reduction in the growth and yield of cotton. The removal of this grass, involving as it does great cost, is one of the established routine of operations in the black cotton soil fields and every care is taken to rid the field of the grass. Whether in this case also the cause may be a kind of poisonous exudation of the same kind cannot be stated, but appears probable. The matter requires investigation.

It is a common belief that the roots of certain plants repel those of others and that these two kinds of plants cannot therefore be grown together. Whether this is really so, if true, whether it is a case of poisonous root exudation are all matters for future investigation. The author remembers experiments in which a large variety of plants was examined by being grown in association with *sandal* to determine their nature as host plants to the *sandal*, which were conducted many years ago by the Mysore Department of Agriculture. This was of course in connection with the question of root parasitism. A similar experiment on a wider basis in the case of the ordinary field crops in this connection may lead to important results.

Mixed cropping and labour saving implements

The introduction of better implements in Indian agriculture has long been one of the directions in which it has been sought to be improved. These implements comprise tillage implements such as ploughs, cultivators harrows and hoes. Sowing implements or seed-drills, harvesting tools, threshing appliances, sugarcane mills and jaggery boiling appliances, water-lifting appliances and some miscellaneous ones like chaff cutters, carts, bullock yokes, bullock shovels, wheel barrows and the like. They have all as their object a better type of work such as deeper tilth, soil inversion, uniform sowing, greater efficiency in reference to each type of work, speeding up of the work, economy in labour or the ability to turn out more work with fewer hands and lastly a certain amount of comfort or lessening of strain whether for men or bullocks, tending to increase their efficiency. There is perhaps general agreement as to the need for securing all the above mentioned objects, except in the case of labour economy. It is desirable that such implements and methods should be introduced as will dispense with the need for a large amount of human labour on the farms and enable the cultivator to farm a larger area with a smaller labour force. This is considered by some as one of the most important needs of Indian agriculture, if it should ever enable the farmer to rise to a higher standard of living than he enjoys at present. The opposite view is also largely held that more efficient agriculture is possible only with small scale farming and that ameliorative methods should be found in co-operation, better organisation of credit, marketing and so on, but keeping as many people as possible on the land and not squeezing them out on to industrial or other urban occupations. Though much can be said in support of either view it cannot be denied that there is scope for considerable improvement in this matter of agricultural implements without the bringing about of any large transformation in the shape of a reduction of the rural population or of a state of largely mechanised agriculture. Much depends upon what kind of labour saving appliances one is thinking of, whether they are, for instance, of the tractor cultivation order with multi-furrow ploughs and later with self binders and threshing machines or combines and so on, or of merely improved implements of a comparatively humbler type which can be adapted to the bullock draft now available with the farmer but which will still be a great improvement on the present methods. If thus the introduction of labour saving implements is called for, it is relevant to consider to what extent the system of mixed cropping will suit or hinder or interfere with such introduction.

Among the various agricultural operations referred to above, it is well known that the shortage of labour is felt most keenly during the harvest. Even where normally there is a sufficiency of labour for ordinary operations, during the harvest season there is always acute scarcity and competition among land holders is great to secure such labour as may be available. Wages are high and much casual labour flocks to the villages during the season to take advantage of the situation. In the tracts of insufficient labour even in ordinary times the difficulty becomes very great and timely harvest is almost impossible and much loss on that account is not uncommon. At present the sickle is the only and universal harvesting tool for all

cereals and other crops which have to be cut down. In some cases as in the harvesting of irrigated *ragi* and even jowar in some tracts, the field has to be gone over and plant by plant has to be handled, for cutting the earheads, except where the earheads are removed after the sheaves are brought to the threshing floor. This perhaps is the last word in slowness in the harvesting of the grain crops. The question is, whether it will not be possible to improve harvesting methods so as to get over this difficulty for labour and to speed up the operation. Indeed so primitive and ancient are the methods of harvesting and the operations on the threshing floor, that they arouse deep and reverent interest in the visitors from the U. S. A. (that land of mechanised agriculture *par excellence*) because they recall to their mind scores of biblical stories of the days of the Pharoahs, if not of Adam and Eve, which they could never have imagined were actually to be seen in these modern days anywhere in the world. It may be recalled that as a harvesting tool in Europe and America the sickle has long gone out of use, and has given place to successive improvements like the scythe, the scythe with the cradle attachment the mower, the mower or the reaper with the sweeprake attachment, the self binder the header and lastly the combined header and thresher. It is really an extraordinary circumstance that the sickle should persist in India so universally and that we have not advanced even to the scythe stage. Some 40 years ago the matter of improved harvesting tool was taken up by the Mysore Department of Agriculture and an implement fit for ordinary bullock draft, viz., a mower and then a reaper were imported and tried for the harvesting of dry land *ragi*, which is the chief grain crop of the country. The implement was found quite suitable for bullock draft and capable of harvesting ten acres a day. There was general appreciation by even conservative farmers of this striking result and this large output of work as indeed was only to be expected, because with the ordinary sickle it will require some 15 to 20 women coolies to harvest a single acre in a day. The *ragi* crop is however very largely grown with a mixed crop of field beans and other minor crops which are fit for harvest only long afterwards, and one row of which alternates with eleven rows of the *ragi*, so that the *ragi* has therefore to be harvested but the mixed crop has to be left standing. This kind of selective harvesting was of course impossible with the machine ; and as the abandoning of the mixed cropping was too radical a recommendation at that time the whole question had to be dropped, in spite of its importance and of its promising character. Where crops which will lend themselves to machine harvesting can be grown pure, the introduction of harvesting machines will be a very desirable improvement ; it is as a matter of fact reported that in some wheat growing districts of the Punjab, a reaper is being successfully used. If only mixed cropping can be given up without any serious disadvantage, the use of such machines can be made general, the machines being owned either by individuals or co-operatively. Mixed cropping will therefore be a hindrance to the introduction of this much needed improvement and agriculture will have to be of the slow manual labour kind, as long as it has to continue. We must not overlook the fact that some other changes will have to come about, especially the prevention of lodging by an earlier harvesting of the crop and the growing of stiff-stemmed and non-lodging varieties, and other consequential changes in

harvesting, field stacking and similar routine to permit of machine harvesting satisfactorily ; there may be a little stubble left on the ground and therefore a reduction in the quantity of straw obtained, there may be a little rough handling of the sheaves and some more shedding of the grain ; these will have to be put up with and set off against the labour saving advantages of the machine. As a hindrance to the use of machines the system of mixed cropping will remain the most serious compared with which these are very insignificant matters.

In the harvesting of the groundnut crop also improvements in harvesting methods are urgently called for, as the present methods of having to use digging tools and manual labour makes the work both hard and slow. If on account of the scarcity of harvesting labour the digging is delayed then the ground (the reference is to the red soils of Mysore and South India) often becomes so dry and hard as to make even digging out of the question, as the cost then becomes prohibitive. Some kind of bullock-drawn implement, is a great need for this purpose, and this is fully realised by the ryots themselves as is evident from the variety of methods employed as alternatives to digging by hand. Thus in the case of irrigated groundnuts the field is given a watering immediately prior to harvesting, and is then ploughed with an ordinary country plough which brings up the nuts, which are then gathered by coolies. In the dry cultivation, on the black cotton soils a special bladed harrow with the blade set at a steep angle is used, which answers the same purpose. In the red soils where the ground sets hard, either a plough is used if possible or the stone threshing roller is first drawn over the field face which loosens the surface and makes ploughing less difficult. Occasionally ploughs of the potato digger pattern are used. All these are only possible where the groundnut is grown pure or where the mixed crop is such that it matures and is harvested before the groundnut. If the mixed crop is different and has to be left standing then these methods are not possible. Cotton, castor, tuver are of the latter type and will preclude anything but selective harvesting with hand tools. *Jowar*, *bajra*, millets are of the former type and their being used for mixture will not be a disadvantage from this particular point of view. Attention may be drawn to another serious disadvantage of mixed cropping in the matter of harvesting. In many of the mixtures commonly adopted, components are such as mature and become ready for harvest at the same time ; examples are rice-cotton mixture, *ragi*, cotton mixture. Harvesting in such cases except when it is carried out with very great care cannot but result in the knocking about and shedding of grain, of damage to the cotton branches especially if it is the American variety with its horizontal branching habit, and in a shaking down of the easily detachable cotton from the bolls and so on. The great care required to avoid or minimise these losses will make the harvesting even slower and more costly than it is already with the selective harvesting which is necessary in mixed cropping.

Mixed cropping has been found to be a serious hindrance in another important aspect also. It has been found in Mysore (at the Hebbal Experimental Farm) that over a series of years the ploughing of the field immediately after the years

harvest of *ragi*, i.e., about the month of November is more favourable to the succeeding year's crop than if the soil is left untouched until the ploughing season of the following year (see under heading number 6). It cannot be definitely stated whether the beneficial effect, is due to any conservation of soil moisture, to the more thorough weathering, or because it enables the soil to absorb the first rains of the following year to a larger extent or other causes. As however the result has been favourable, the practice has been recommended for general adoption. The practice of growing a mixed crop of field beam or some times red gram in the *ragi* makes it necessary that the ploughing should be delayed until after this mixed crop too should be harvested, by which time (say about the end of January or the middle of February) the soil surface becomes very dry and hard, making ploughing impossible. So to get over this difficulty, a six shovel cultivator, a disc harrow and such implements have been recommended and introduced, although these can stir the soil and can in no way be a substitute for ploughing. Were it not for the mixed crop a good ploughing can be given and the full advantage secured without having to be satisfied merely with this shallow discing or harrowing. It is interesting to add that the importance of this ploughing is well recognised in some parts of the state and ryots invariably plough the field between the rows of the mixed crops immediately after the harvest of the grain crop and for this purpose go to great pains in moving the vines of the field bean crop this way and that, so as to save it from damage during the ploughing. As a dry farming practice this ploughing has been found very beneficial, but mixed cropping renders it difficult to carry out or to be carried out in such a manner that the full benefit can be secured.

Mixed cropping as related to a balanced nutrition

It is a common observation that the diet of the people of India is insufficient and ill-balanced. While the total nutrition requirement in terms of calories falls short of what may be considered an adequate quantity per individual, the lack of the much needed variety in the shape of a proper protein supplement, and of even a carbohydrate supplement in the shape of oils and fats, together with a sufficient addition of the accessory or protective foods in the shape of milk or animal protein and vitamins is a matter which has been emphasised by nutrition experts. Leaving aside the question of a general insufficiency of food, which can be remedied only by a large increase in the production of food, it may with much reason be held that the system of mixed cropping makes a very material contribution towards remedying the other defects viz., the lack of balance. In all the tracts where mixed cropping is generally practised, a veriety of crops is grown both different kinds of food grains and pulses (including the groundnuts which is both a pulse and an oil seed) and largely included in the dietary of the local population. The diet of all farming communities in such tracts is composed of a mixture of the staple of the tract, as the main cereal, the chief pulse as the main protein supplement, with other grain and pulse crops which are grown to a smaller extent affording an appropriate variety. Groundnut, gingelli and safflower to the extent that they may be consumed as such supply considerable portion of the fats in the food. In

mixed cropping this is easily possible, as this variety of crops is grown unfailingly year after year. In the system of growing pure crops, on the other hand, such a variety can be secured only by the laying down of many fields or plots each devoted to a particular single crop and by the adoption of a suitable rotation which can include all these crops. In practice such a course will be found almost impossible and especially so for the small farmer. As a matter of fact there is a great deal more of the pulse crops consumed in households in the dryland tracts than in the delta and other tracts where rice is the single crop grown. 'In rice eating areas where pulses are most needed their intake tends to be smallest'. Moreover there is also considerably more variety in the kinds of pulses consumed in these tracts. In the pure rice tracts the *dal* of *Cajanus indicus* is the chief and about the only pulse consumed, and blackgram and greengram are consumed to a smaller extent, and some of the other pulses figure to an insignificant extent. All these moreover are purchased products and the consumption is therefore generally small. On the other hand among the farming classes in the dryland tracts where the system of mixed cropping prevails most, other pusles like field beans, horsegram, kasari lentils (*Lens esculentis*), Bengal gram all figure to a larger extent, in addition to the redgram, blackgram and greengram consumed in the rice tracts. Presumably then the diet of the mixed crop farmer is better both on account of the larger proportion of the proteids consumed in the shape of the pulses and by reason of the variety among them.

This matter requires however to be gone into a little more deeply, in order to appreciate its full implication and its practical bearing on mixed cropping. It can be elucidated only from the chemical point of view, on the basis of investigation into the composition and nutrition value of the different grains and pulses, and particularly the contents of proteids, their nature and characteristics from the nutritional point of view. What are their comparative values as suppliers of proteids in animal nutrition? At present the composition of the different pulses is largely given only in terms of the proximate constituents, such as proteids, starches or carbohydrates, fats and so on, and very little information is available as to the quality of these particular constituents, although it is known that their value as human food is very materially influenced by this factor and does not altogether depend upon the total percentage of such constituents. The different kinds of proteids (such as lysine, histidine, argenine, crystintyrosine and tryptophane) of which the total proteids are made up and their relative proportions have not been determined for all the different pulse crops of India nor have other important peculiarities like their biological values, digestibility etc., been determined both chemically and through nutrition experiments. Such data are lacking even in the case of individual pulses and much less are they available in the case of mixtures of the pulses with various cereal foods like rice, wheat, *jowar* or *bajri*. The same remark applies to the composition and character as human foods of these staple food grains themselves. In the absence of scientific data of this kind it will be impossible to assess the value of the different foods whether cereals, pulses or oil-seeds, either by themselves or in various combinations. That differences do exist other than or even contrary to what one may infer from the proximate composition

in terms of the total percentage of each food element, is a belief almost universally held in the country, both as the result of actual experience and according to the teachings of indigenous medical systems. Such differences are a matter of every day experience in Indian households and there is altogether an astonishing amount of what may be called ' kitchen lore ' in the possession of our womenfolk regarding the differences in quality, behaviour and suitability or healthfulness, of these various food materials, both in themselves and in mixture with one another. Thus green-gram is supposed to be the most easily digestible among the pulses, cowpeas, field beans, and Bengal gram *dal* are hard to digest, and have a tendency to produce flatulence, red gram *dal* as tending to promote growth, black gram as about equal to animal food, and so on. That blackgram is quite different from others is easiest to notice ; the dough is mucilageous and plastic and indeed is used as a plastic adhesive like casein in closing leaks in sugarcane juice boiling pans. It is also sometimes stated that its use was popularised by Budhist monks as a substitute for meat. To what extent these beliefs have a scientific basis and can be taken as correct cannot be stated as matters stand at present with the very meagre almost negligible scientific data available.

The practical value of such definite knowledge in this respect may be said to be two fold, viz., in determining what will be the best mixtures of grain and pulse and whether and to what extent one or the other of the pulses may be used as substitute for proteids of animal origin. Taking the question of correct mixtures attention may be drawn to the fact that in the daily dietary of the people it may be noticed that it is red gram *dhal* that largely goes in mixture with rice, field bean *dhal* with *ragi*, Bengal gram with wheat or barley, and many kinds of pulses with the dry grain *jowar*, *bajri*, and the millets. This preference to one or the other of the pulses may be merely due to the fact that such pulses happen to be cultivated in the tract and are therefore locally available and are therefore dictated only by convenience and that no special significance can be attached to them. It must be said on the other hand that apart from this circumstance, the pulse crops red gram, field beans Bengal gram and perhaps lentils enjoy special popularity and are to be regarded as major pulses and are always secured either from local grown produce or if necessary from outside, so much so that the preference has something more behind it than mere convenience. Just as in the case of the cultivation of the mixed crops some may be regarded as compatible mixtures and others cannot be so regarded, similarly in their use as mixtures in food with particular cereals and pulses some combinations may be advantageous and others not. Perhaps compatibility on the field as disclosed by present practices may be parallel with compatibility on the table as food. In any case it is obvious that those pulses which should prove the best mixture with any particular cereal grain as a food should be the most desirable for mixture on the field also, provided other agronomic considerations are not against such mixture. The suggestion made ' it will be appropriate to divide the country into different regions irrespective of provincial and State boundaries such as a rice region, a wheat region and a mixed region and to work out the requirements and availability of foods in respect of those ' deserves to be taken up. for more

reasons than those contemplated by the authors (*I. C. A. R. Memorandum on the Development of Agriculture and Animal Husbandry*, p. 17).

Reference may now be made to some interesting results of an investigation into the comparative merits in regard to their biological values of certain pulses when used as mixture with rice. The pulses taken up for this investigation are red gram, black gram, green gram, Bengal gram and soya bean, and the grain taken up was milled rice (not par-boiled). Comparison was also made of the pulses in the same mixture with the addition of skimmed milk. The results as far as they relate to the first series alone are given in the Table VI.

TABLE VI

Biological values of certain pulses when used as a mixture with rice

Sources of proteins	Biological value	Digestibility coefficient	Average increase in body weight
Raw milled rice plus red gram	70	81	7·4
Raw milled rice plus soya bean	68	84	6·5
Raw milled rice plus Bengal gram (*Cicer arietinum*)	66	85	6·8
Raw milled rice plus black gram	61	82	5·9
Raw milled rice plus green gram	59	90	7·5

It is seen that when pulses are eaten with rice, green gram (*Phaseolus radiatus*) and red gram (*Cajanus indicus*) appear to act better than Bengal gram or any other variety (Swaminathan, M. 1937, *Ind. Jour. Med. Res.* Vols. 1 and 2, pp. 24 and 25).

Investigation of this kind carried out with the other important grains like wheat, *jowar*, etc. is likely to lead to interesting and important conclusions on this matter and is therefore to be very strongly recommended. It has to be remembered that in respect of the portein content and its character the grains differ considerably from one another. Moreover the proteins of the grains appear to be sharply distinguished from those of the pulses and also of other kinds of produce. Thus the biological value of the protein in those of the grains were found to be as follows :

Ragi, 89·9 ; rice (polished), 80 ; *jowar*, 83 ; maize, 60 (B. N. Acharya, S. P. Neogi, and V. N. Patwardhan, in *Ind. Jour. Med. Res.* 1942, p. 79).

Ragi, 89 ; rice, 80, *jowar*, 83 ; *bajri*, 83 ; Italian Millet, 77 ; wheat : 66 (Swaminathan, M., 1938 *ibid*).

In regard to the distinct nature of the proteins in the cereals as against those in pulses, attention may be drawn to the conclusions by Staker and Gortner, viz., 'the peptonisation behaviour of the various groups of related seeds (such as grains,

pulses, oilseeds) appear to be rather distinct and characteristic of each group' (Physico-Chemical Studies on Proteins, E. V. Staker and R. A. Gorter, *Jl. of Phy-Chemists*, 1931, pp. 1565-1605). These authors further remark that the whole question of protein individuality, protein classification and protein isolation needs to be critically studied.

We now come to the second point, viz., if the proteins of any of the pulses are allied in composition to proteins of animal origin closely enough to admit of their use as a substitute for the latter partially or fully, and again if a mixture of the pulses will make it a more efficient substitute for animal proteins than single ones. These questions are of particular importance in a country which is so largely vegetarian in its food as India, where on this account the supplementing of the usual food with animal proteins in the form of milk and milk products is very much stressed as that is about the only form of animal proteins which may be acceptable to the stictly vegetorian classes. If one or more of the indigenous pulses can to any extent be used as a subtitute for auimal protein then the problem of nutrition becomes somewhat less difficult. As everybody knows, the same extent of land can feed a larger number of people if it grows food for direct human consumption instead of as feed for livestock which may in turn furnish human food either as milk or as meat, or in other words, that a vegetarian population can subsist on a smaller area of land than a meat eating population. A positive finding with regard to the value of the pulse proteins as substitutes for animal proteins will therefore lead to very important results. Unfortunately (as far as we are aware) little or no research has been carried out in elucidation of this aspect of the question.

R. K. Pal in his review of the literature on this subject has attempted to assess the comparative values of the pulses in this respect by combining together all the data regarding biological value, digestibility, total protein content, net protein value, and percentage of cystine, tyrosine, tryptophane and histidine. Arranged on this basis Bengal gram and black gram both stand first in the order of merit, and green gram, lentils, cowpeas, soya beans come next in order ; red gram, horse gram follow next, and field pea, field beans, and *khesari* come last (R. K. Pal, *Ind. Jour. agric. Res.* Vol. IX, Part I, 143).

The different aspects of this complex problem require to be studied, both chemically and biologically and the importance of such studies cannot be over emphasised. Conclusions of the greatest value are likely to be reached which can be made use of in the recommendations for suitable mixed crops of pulses to different cereal regions in the country.

Mixed cropping and utilisation of space

One of the chief motives in resorting to mixed cropping is certainly the object of utilising all the space possible for the raising of crops, rather than leave any portion of the field bare of crop. The whole of the area has to be ploughed or dug, cleaned of weeds and brought into a good state of tilth and manured, and later irrigation, weeding, watching and general attention has to be paid in any case ; why should not all these facilities created at great cost and labour, be utilised to the fullest extent

possible ? Failure to do so only means woeful neglect and waste which no cultivator can afford. If suitable mixtures of crops can be arranged, so that this object may be attained without serious interference of one with the other such mixed cultivation should be considered the best in the interests of the farmer and one calculated to make the best use of manure, labour and land. It is largely some idea of this kind that underlies the system. The idea is very clearly seen in many vegetable gardens ; around Bangalore for instance a favourite mixture is knolkohl, and sabsige (*Peucedanum graveolens*) and *chakotra* (*Atriplex hortensis*) which are sown together. The *chakotra* is pulled out first, then comes the sabsige and lastly the knolkohl. Another mixture is *chakotra* and amaranthus sown together and a month later celery transplanted in among them. The first two are removed one after another and the celery covers the ground completely and is harvested after three months. Likewise amaranthus, carrots, English radishes, knolkohl are all sown together and are removed one after the other, the carrots being the last to be pulled out. Cauliflowers or cabbage are planted in mixture with chakotra, sabsige and amaranthus, these last are removed first, and then the cabbage and cauliflower cover the ground completely and are removed in from three to four months. Along the margins onions are sown and these are removed in six to eight weeks. In all these cases the quick growing crops are sown in among the more leafy and long duration crops like cabbages, cauliflower plants, so that the former can be gathered and removed by the time the latter grow sufficiently large to need and occupy the full ground ; to leave the ground bare until this time is considered wasteful, and hence these catch crops are sown ; a succession of crops is the result giving some money income every time ; the quick growing crops shade the slow growing seedlings and give protection and the gradual removal of the catch crops result in a certain amount of forking but the money income for the full utilisation of the space is certainly the main consideration. Some crops can be so grown that they do not take any ground space worth mentioning and therefore without competing in this respect with a long duration crop, because they can be trained on poles and vegetative growths carried up clear of the ground. A most curious instance of this kind was the training of the creepers of vegetable crop (bitter gourd) over strings reaching from the ground to the eaves under the roof, leaving the ground free for other crops ; another familiar example is the training of creepers of some kinds of beans over upright trellises rather than over overhead frames *pandals*, so as to economise space. This has its counterpart in field husbandry in the growing of maize or fodder *jowar* with climbing vines like cowpeas or horse gram.

In the case of catch crops in among sugarcane, in the early stages when the sugarcane is very young and has not tillered and grown leafy enough to preclude catch crops, it is a natural desire to utilise the space between the rows for some mixed crop. So in the case of cotton and castor, the desire to grow an inter crop during the time that they take to grow large and bushy enough to preclude it, is natural. If there should be no mixed crop of this kind, weeds will in any case come up and occupy the ground and will necessitate frequent hoeing with bullock or hand tool ; the growing of the inter crop prevents such usurpation and substitutes a profitable crop for a pest which has to be removed at considerable cost.

If instead of a mere catch crop, which may be dispensed with if necessary a regular food or other much needed crop has to be grown in this way as a mixed crop, making use of this interspace, then this method of space utilisation assumes greater importance. If such mixed cropping should be considered undesirable, then the alternative will be to grow such a crop on a separate field or plot. This may not always be possible, especially in the case of ryots with limited land. This method of the full utilisation of the available interspaces dispenses therefore with the need for additional land, and enables the smaller ryots to raise many of the crops they may need on the limited land they may possess, which but for this system will be impossible for them. In all these cases the observation made with reference to their experiments on the practice of growing groundnuts as a catch crop between the rows of sugarcane by the authors (V. C. Valma and J. P. Tiangsong) that ' inter cropping saved more land, more preparatory cultivation and gave a money return ' is very apt and fully applicable. Whether the mixing results in the reduction of the main crop (sugarcane) as in their experiment or whether the returns from all the crops taken together will be such as to make up for such reduction in the yield of the main crop are important qustions to be considered. As far as the smaller cultivators are concerned, the economy in the utilisation of space and possibility of raising their requiremets from a single piece of land will outweigh such considerations and with them it will always remain a popular practice, the wisdom of which cannot be questioned.

The variety of crops grown in this manner even in field husbandry is surprisingly large. On the black cotton soil in among the *jowar* crop it is usual to grow red gram, cowpeas, Deccan hemp, cucumbers, chillies, *bhendi*, brinjals and even some gourds; in among *bajri* are grown similarly cluster beans (*Cyamopsis psoralioides*), *matki* (*Phaseolus aconitifolius*), gingelli, Deccan hemp, and in among *ragi* to grow fodder *jowar*, red gram, fieldbean, millets, *niger*, cowpeas, mustard, sunnhemp, and even castor, in among cotton to grow Italian millet, black gram, gingelli, okra (*bhendi*) or red gram, green gram, black gram, Deccan hemp, gingelli in wheat to grow gram, linseed, rape, barley and so on. In the statements of mixed crops from the different provinces appended to this article will be seen a complete list of such varieties.

It is the crop mixtures which are grown under irrigated garden cultivation mostly under well irrigation and to some extent as purely rain fed crops where the rainfall is regular and plentiful that illustrate this principle of space utilisation best. In addition to the combinations already mentioned the following may be also selected as noteworthy: Chillies and onions under *agathi* (*Sesbania grandiflora*), turmeric with vegetables, plantains under-planted with yams or/and turmeric, ribbed gourd with *bhendi* (Madras) potatoes under patol (*Trichosanthes dioica*), cowpeas, black gram and horse gram as under crops below *tapioca* (Travancore and Cochin) *yams*, and pumpkins on overhead frames with turmeric and ginger as under crops (Assam) and *furan* (*Amorphophallus campanulatus*) *yams* (*Dioscorea* spp.) *alu* (*Colocasia antiquorum*) and ginger (Bombay).

The economics of mixed cropping

How do the returns from mixed cropping compare with the returns from pure crops ? It will be necessary to compare not only the money returns but also the return in the shape of actual produce, because one may be more important than the other according to circumstances. The answer to this question will obviously decide the choice between the two systems, certainly with regard to small scale farming by individual cultivators and possibly also with regard to large scale cultivation whether it be by a capitalist or by a co-operative agency of individual cultivators. We have discussed the subject in most of its aspects and drawn attention to what may be called the pros and cons of the question. Some of the advantages may be such as to strongly weigh in favour of the one or the other notwithstanding the economic or money returns from either, much depending upon the individual cultivator or the time and place. All the same the economic aspect must be deemed the most important, and should largely decide the merits of the one against the other. This aspect of the question has been studied to some extent by the different departments of agriculture in India off and on in the past. The suggestion made by Sir John Russell in his report on the work of the Indian Council of Agricultural Research, viz., ' The agricultural and economic aspects of mixed cropping should be studied, in view of the widespread use of this practice and the probability that some crops mix better than others ', may be said to have been acted upon for a considerable period prior to his inquiry and report. It cannot however be stated whether such experiments as have been so conducted in the past were laid out in the manner prescribed in recent years so as to conform to the accurate statistical technique and if they have been interpreted statistically. If they have not, as appears probable, then a further case is made out for a uniform and correct scheme of experiments being laid down with reference to the crops selected. It is also necessary to observe that one of the chief merits of the system of mixed cropping is that it serves as a kind of insurance against crop failures due to a shortage in the annual rainfall or of an abnormal distribution thereof. Experiments laid down in this behalf must therefore take note of this seasonal factor and must be conducted over a long series of years so that as great a variety in the rainfall and its distribution as possible may be covered ; and it is only then that the results can carry conviction and be capable of practical application.

Attention should be drawn in this connection to another important consideration, viz., the method of interpretation or the basis of comparison. This point has been raised by Nicol and requires serious consideration. Nicol suggests that ' in comparing the yields from mixed crops as against pure sown crops the basis of comparison should take note of the actual space utilised by the crop in each case '. If, for example, in a *ragi*-fodder *jowar* mixture six rows of *ragi* alternate with one row of *jowar*, then the yield of *ragi* from an acre of that field should be reckoned as the yield from six sevenths of an acre of that field for purposes of comparison with the produce from an acre of *ragi* grown with no mixture. Likewise in a wheat-mustard mixture, in which five rows, let us say, of the grain crop alternate with one row of the mustard crop then the actual yield of grain from that field of mixed crop should be regarded only as the yield from five sixths of an acre, for purposes of

comparisons with the yield from an acre of the crop grown pure. Nicol points out that compared in this way a legume-cereal combination has benefitted the cereal and led to a higher yield although interpreted in the ordinary way quite the opposite conclusion may be reached. It is not known whether in all the experiments conducted in the past the comparison has been made on this basis or without making any such allowance for the amount of actual space utilised by the crop.

In the case of all the crops which have a similar habit of growth and which can therefore be grown at more or less the same distance or space between the rows, such as say, the different grain crops like wheat, rice, *jowar*, *bajri*, *ragi*, Italian millet, and the different millets, the non-grain crops like *Hibiscus cannabinus*, sann hemp, jute and the low-growing leguminous crops like green gram, black gram and Bengal gram, this principle of space utilisation in proportion to the number of rows occupied by each of the two or more crops in the mixture can be admitted. All these crops grow either tall and with very little spreading branches or are small and therefore whether they are grown pure or mixed, the same narrow spacing between the rows is possible and allowed. Space utilisation can therefore be taken as proportional to the number of rows occupied by either crop in the mixture. On the other hand in the case of mixtures in which the crops have different habits of growth, one tall or short but not branching much and the other bushy and many branched, the utilisation of space by the different crops cannot be taken as proportional to the number of rows occupied by each. Take for example, the Italian millet cotton mixture with five rows of the grain alternating with one row of cotton, the space occupied by the cotton in the mixed crop will not be found to be materially different from that when the crop is grown is pure. Whether grown pure or mixed the distance between one row and another of cotton will have to be more or less the same. In the mixed crop the spacing of the cotton may be about three feet between the rows (this space being occupied by five rows of the grain crop Italian millet) and in a pure crop of cotton also, either the same spacing will have to be given or as is more usual a spacing of two feet is allowed. If the spacing is three feet apart, then whether pure or mixed the cotton occupies the same extent of ground. If the spacing is two feet in the pure crop as against three feet in the mixed crop, then an allowance for the $33\frac{1}{3}$ per cent less space occupied in the mixed crop than is permissible in a pure crop will have to be made. The same observation will apply in the case of the *jowar*-redgram mixture, castor-horsegram mixture, and such similar mixtures. In mixed cropping the rows of these crops like cotton, redgram or castor are made larger or smaller in number according to the wishes of the cultivator who may alter the proportion of one crop to another as it may suit his requirements, irrespective of the normal or the usual width required in a pure crop. If the principle of space utilisation is accepted as it should be, then in comparing the yields of this particular type of mixed crops under the two methods of pure and mixed cropping, a standard width which is either the usual one for this kind of crop or what may be deemed the most suitable, will have to be taken as the basis for space utilisation in the mixed cropping by this particular crop. This aspect of the subject is a very important one and requires special attention and study.

We may now bring together the relevant information available in respect of the results of experiments comparing the two systems conducted in the different provinces. Nearly all the Directors of Agriculture who were addressed in the matter of furnishing information about the results of experiments carried out in their respective departments have stated that experiments in this regard are only just being planned or will be planned later on as the result of the recommendations of the Council, so that the amount of information available is comparatively small. It is also especially worthy of mention that Rao Bahadur G. N. Rangaswami Ayangar who led the discussion on this subject at the meeting of the Crop and Soils Wing of the Council in 1942 has collected and published a good deal of information (vide *Indian Farming*, Vol. III, No. 5, May 1942). The experiments referred to by him are classified below into (*a*) those in which the mixed cropping was found advantageous, (*b*) those in which it was found not profitable and (*c*) those in which the results were inconclusive.

(*a*) *Mixed cropping profitable.* At Pusa it was observed by Howard that there was a marked advantage in growing mixed crops of gram and wheat, on soils where combined nitrogen is the limiting factor.

In a rotation experiment conducted at the Poona Agricultural College Farm, it was observed that *bajri*-red gram mixture grown every year gave the highest return over other rotations.

At Koilapatti it was observed that *bajri* (*Pennisetum typhoideum*) when grown mixed with red gram, field bean or Bengal gram yielded as good as and sometimes better than, the cereal crop when grown as pure crop, if the crop was sown early.

At the Gokak Farm in the Bombay Presidency, a mixed crop of maize and red gram in rows gave decidedly better results than growing two crops of maize one after another.

In rotation experiments at Pusa, the highest gain in soil nitrogen was in one series with a mixed crop of maize and black gram. The mixed crop gave the highest economic returns.

At the Guntur Agricultural Station a mixed crop of cotton and groundnut proved to be the best when compared with cotton and Italian millets, cotton and rice and cotton alone.

At the Nandyal Agricultural Station a mixture of cotton and horse gram (*Dolichos biflorus*) gave yields similar to cotton grown alone with the added advantage however of the produce from the horse gram which was a direct gain.

At the Gokak Farm a mixed crop of cotton and Italian millet was better than growing cotton alone, an experience contrary to that at Hagari.

At the Dharwar Farm it was observed that cotton and groundnut in alternate rows gave better results than cotton and groundnuts in blocks.

At the Palur Agricultural Station results over a number of years led to the conclusion that mixed cropping of groundnuts and cereal is better than rotation, and that *bajri* is the best cereal to grow as a mixture. At the Thindivanam Station

the best results were obtained from growing groundnuts in association with *jowar* castor, red gram or cotton (although in all cases the yield of groundnut in mixed cropping was depressed).

In the United Provinces it has been reported that growing groundnuts between rows of red gram has been profitable.

(*b*) *Mixed cropping is not profitable.* Experiments in some stations in the United Provinces have shown that the local practice of growing mixed wheat and gram on irrigable black soils is less profitable than sowing wheat and gram in rotation.

At the Cotton Breeding Station in Coimbatore the mixing of pulse with *jowar* did not benefit either the *jowar* or the succeeding crop of cotton. The pulse reduced the straw yield of *jowar*.

At Nandyal, Pillipesara (*Phaseolus trilobus*) in mixture with *jowar* had a depressing effect on the yield of *jowar*. At Guntur there was no increase in yield in growing this mixture.

At Hagari, in the Cotton-*Setaria italica* mixture the yield of cotton was lower than in the pure cotton crop.

At Koilpatti, Bengal gram, horse gram and coriander were grown mixed with cotton and compared with cotton grown alone. The monetary return of the mixture was less than that of cotton alone. At the Central Farm at Coimbatore, mixed crops of cotton were not found profitable financially, as the price of cotton at that time was very high.

The depression in the yield of groundnuts in mixed cropping observed in the Thindivanam Station has already been referred to.

(*c*) *Results inconclusive.* At Koilpatti various other pulses (than red gram and horse gram, already mentioned) tried along with cotton led to no definite conclusions.

Mr. Rangaswami Ayyangar concludes, by saying that experiments conducted at various Agricultural Stations have not led to any definite results with regard to the suitability of any particular subsidiary crop or the benefit derived by growing such mixtures.

The experiments conducted in the Madras Presidency nearly all of which have been referred to above are summarised in greater detail in a note by the Director of Agriculture, Madras (vide. Appendix II). The Director observes 'with the exception of a few Stations, viz., Guntur, Palur and Thindivanam, the pure crops gave the highest money return. At the three stations mentioned above the rainfall and soil conditions were obviously favourable for crop mixtures'.

In experiments comparing the yields from wheat-gram mixture with those from wheat and gram grown pure conducted in the Nagpur Farm, Central Provinces, the financial advantage was in favour of the rotation of wheat with gram both being grown pure as compared with a wheat-gram mixture every year, although the difference was not very striking. The wheat yielded at the rate of 895 lb., per acre in the pure crop and the gram yielded 453 lb., as against 553 lb., of wheat and 145 lb., of gram (all averages over a period of 16 years) so that taking a two year crop, the mixed crop gave on an acre 1,106 lb., of wheat and 290 lb., of gram while the pure crop gave only 895 lb., of wheat and 453 lb., of gram. The total

grain during the two years period was more in mixed cropping but the gram was less. Financially the pure crop is reckoned as having scored. In another experiment designed directly to compare the two systems with wheat and gram carried out over a period of ten years, the average yield of the pure crop of wheat was 348 lb., per acre while that from the mixture (two thirds wheat and one third gram) was 244 lb., of wheat and 119 lb., of gram. Calculated proportionately the wheat yield from the mixture will work out somewhat (but very little) higher than in the pure crop, being 244 plus 128 or 366 lb., per acre as against 348 lb., in the pure crop. Taking only the crops actually harvested the financial result here also is stated to be in favour of the pure grown wheat crop, (vide pages 348-351 a consolidated recotd of the Fievd experimental works carried out by the Department of Agriculture in the C. P. between 1900-1930, by R. G. Allen). These experiments are very noteworthy because they have been carried out over a fairly long period, viz., 16 years and 10 years respectively.

It is reported by the Director of Agriculture, Bhopal, that 'economic results of mixtures are better than sown pure.' The report gives the yields of individual components of mixtures of different crops with wheat, but does not give comparative figures for pure crops. It is also stated that the following proportions have been found the most profitable, viz., wheat and linseed 50-50 ; wheat and gram 75-25 ; and gram and linseed 50-50.

In Mysore the question has been studied in considerable detail, and from more than one angle, viz., in relation to the use of a better harvesting implement, in relation to the ploughing of the fields in the autumn, in relation to the conservation of soil moisture and lastly in relation to the sowing of pure selections in preference to the sowing of mixtures. The work as it relates to each of these aspects has already been noticed in the respective headings.

Comparative experiments to find out the yields and financial returns from pure and mixed cropping were laid down in 1915 and were continued for four years until 1918. The comparison was between *ragi* (*Eleusine coracana*) grown pure and *ragi* grown in mixture with field beans (*Dolichos lab-lab*) which is the customary method prevalent in the state. The experiments were quadruplicate plots and the results were as in Table VII.

TABLE VII

Grain in lb., per acre

——	1915	1916	1917	1918	Average for 4 years
Ragi pure	440	675	850	314	570
Ragi mixed with field bean and *jowar*	325	807	780	120	508
	142	152	52	88	109
	77	121	40	..	60

'The results indicate pretty clearly that the growing of a mixed crop is more profitable than the growing of a pure crop. If we exclude straw the average value per acre of the pure crop was roughly Rs. 18 and that of the mixed crop roughly Rs. 25 per acre.' Comparisons have been made in subsequent years also with the same result, viz., the mixed cropping was found more profitable financially. Dr Coleman however observes 'notwithstanding this considerable difference it is still quite possible that the advantages which accrue from early ploughing which can be done only when a pure crop of *ragi* is grown would outweigh the undoubted increase due to the mixture with a pulse crop. This must however remain a subject for future investigation'. (The Cultivation of *ragi* in Mysore by *Leslie C. Coleman, Bulletin No.* 11, *general series ; Mys. Dept. of Agric.* 1920, pp. 11 and 12).

An interesting instance of a profitable form of mixed cropping is reported from the Indian Sugarcane Station, Coimbatore, although the crops concerned in this mixture are only green manure crops. In this Station the practice of growing mixture of two green manure crops together in preference to pure single crops was commenced in 1936-37. The mixtures were (1) field beans (*Dolichos lab-lab* and *pillepesara* (*Phaseolous acontifolious*), (2) field beans and sannhemp and (3) sannhemp and *pillepesara*. It was found that (*a*) the mixture was a better cover on the soil and that it suppressed weeds more completely and (*b*) that the yield of green material from the mixed crop was 30 to 40 per cent higher than from the pure crops. (Letter to the author from Mr. Nanda Lal Dutt, Government Sugarcane Expert, Coimbatore).

PART II

Mixed cropping with reference to some of the principal crops

Rice

It may be thought that the peculiar conditions under which rice is almost universally grown, viz., under irrigation which is so copious and continuous that water has to stand in the field several inches deep, and is often grown under absolutely flooded conditions where water stands several feet in depth, no mixed cropping will be possible as few or no crops of agricultural importance can grow under such conditions. Nevertheless the advantages such as they may be of mixed cropping are so highly recognised that strange as it may seem, mixed cropping is practised even with this crop. The mixed cropping under these conditions takes the form of growing two varieties of rice itself, and not a crop different from rice. The varieties grown are either rices with different periods of maturity, such as one maturing in four months with another maturing in seven or eight months ; or rices which differ in their hardiness, such as one which requires steady and ample irrigation with one which is not so exacting in its requirements for irrigation and will stand a certain

amount of insufficiency of water ; the varieties also differ in their quality, one being fine and the other less so if not definitely coarse. These two different kinds of mixtures illustrate very clearly the two main considerations underlying the practice of mixed cropping in general, viz., 1. a more economic utilisation of time or the length of the crop season, of the area available for cultivation and of the labour involved in cultivation and 2. a kind of partial insurance against a total failure od crops.

The following are the mixtures which come under the above two classes :

1. *Mixture of two varieties of rice*—In the Cauvery Delta in the Tanjore District of Madras, the system prevails of growing the Kuruvai variety of rice as a mixed crop with the Ottadam variety. The former is a four months variety and the latter takes eight months. The practice is to mix the seeds in the rates of one of Ottadam to four of Kuruvai and sow the mixture in a nursery and later on transplant the mixture of seedlings ; both grow together and the Kuruvai matures in 3 to 3½ months. The whole field is now harvested, the grain being only the Kuruvai and the straw a mixture of the two varieties. Incidentally it will be seen that the Ottadam straw is not straw in the strict sense but is really a kind of hay, that is grass cut green and before the grains formed and drained it of its nutrients. The Ottadam now grows from its stubble and matures a crop in another three to four months and is harvested in its turn. This is a truly remarkable practice and it may be doubted if it has its parallel anywhere. The Kuruvai matures in its own peculiar season and the Ottadam in its own season. The alternative if two pure crops have to be grown will be to grow the Kuruvai in the early season and another short duration crop in the following half of the crop growing season (which in the mixed crop system is occupied by the Ottadam crop) ; this part of the season may or may not be suitable for this purpose and an assured or successful crop may be doubtful, in any case. If the Ottadam has to be grown pure, it will take eight months to mature and at the end, the crop may be full or only partial depending upon the seasonal conditions, while the long interval of eight months may be really too trying for many ryots and for their cattle, as few among these have a sufficient reserve of grain and fodder to enable them to carry on for such a long time.

It is not known whether there are any economic advantages in growing these pure in the above manner, sufficiently great to weigh against the mixed cropping to what extent, that is to say, the yields from pure grown Kuruvai and pure grown Ottadam are higher than from mixed crop growing and if so whether such yields can be counted upon over a long series of years under conditions prevailing in the tract.

Experiments have been conducted with another alternative to this method viz., growing a mixture of short and long duration varieties in comparison with a pure crop long duration variety. It was found that with a particular short duration variety (viz., Adt. 3), the combination gave a larger yield than the pure long duration crops (Maratur Station, Madras Province). Similar experiments on the Samalkot Farm (Madras Province) showed that the yield was the same both with the single cropping as well as in the mixed cropping, and that the latter was in addition found

to involve more expenditure. It is stated that in Tanjore the practice is now on the wane, and that in the Godavari Delta 'the system is definitely unremunerative for lands of average fertility or where the planting has to be done late' (*K. Ramiah* in 'Rice in Madras', pages 64 & 65).

We may point to one advantage of a pure Kuruvai crop, viz., the possibility of growing a leguminous fodder crop after the harvest of the Kuruvai. As the cultivation of rice will not permit of a rotation with other crops (except in special cases and in any case to a very small extent, such as where sugarcane, plantains, betel vines, turmeric, tobacco, etc., are grown) and as the need for some nutritious fodder is always great in these tracts where the condition of the cattle is deplorably low, such fodder crop growing may be a desirable practice, if the soil and other conditions will permit.

In the Cochin State a very similar or almost identical practice prevails, in which two varieties of rice called Veruppu and Mundakam are grown mixed. The following is a description of the method :

'The Virippu seed is a short duration seed, four to four and a half months in duration and the Mundakan seed is long duration seed standing in the field for eight months. Both the seeds are sown mixed together in the month of May. The Virippu (short duration) seed grows tall quickly, flowers earlier and it is harvested in September. At the time of the harvest of the Virippu crop the plants of the Mundakan crop remain stunted in the field, almost completely enveloped underneath the Virippu paddy. The plants of the Mundakan crop are not cut at all along with the Virippu harvest. After the Virippu harvest is over in September, the Medom crop which remained smothered under the Virippu crop till then, grows quickly in height and thickness and completely covers the field (Director of Agriculture, Cochin State).

It may be observed that many rices yield a small crop of grain from the stubble, if the latter is allowed to grow. It is not known whether the early variety in the above cases gives any such crop at all ; if it does then the later harvested rice will contain grains of the early variety also mixed with it, which will be a feature much to be deprecated in this practice of mixed cropping.

A very similar system of mixing together of two varieties of rice and growing them together prevails in Bengal and is described by Mukerji (*Text Book of Indian Agriculture*, by N. G. Mukerji). This is his description.

'A peculiar kind of boro rice is known as rayada or *bhasa-naranga*. This is sown along with ordinary boro-rice in December. The young stems are shorn when the young crop is removed, but this does not seem to do the rayada any harm. It continues to grow in water attaining to a height of 10 or even 20 feet and is not harvested till September or October, thus remaining on the land for ten months. Only the ears with a foot and a half of straw are harvested, the rest of the straw or *nara* being left to rot on the land or gathered and set fire to.'

Similar mixtures of rice plus rice are reported as prevalent in many parts of Bengal, where the combination is of *aus* and *aman* rices.

2. *Mixtures of rice with other crops.* A crop other than rice which is sometimes grown in mixture with it under these heavily irrigated or flood conditions is Jute. The *aman* variety of rice is thus grown in mixture with jute (Capsularis) in the Districts of Dacca, Faridpur, Comilla and Rajshahi.

3. *Mixtures of rice with other (dry) crops.* While the above exhaust mixed cropping under the special conditions of rice growing, rice is grown as a mixed crop with a large variety of other crops under the ordinary rainfed conditions of dryland crops. In these situations rice is mostly a subordinate crop. The mixtures consist of one, two or more crops, and comprise cereals, pulses and other crops. The following is a list of such crops which number 16 in all.

Cereals

Jowar

Italian millet

Maize

Kodo millet (*Paspalum scrobiculatum*)

Panicum miliare

Pulses

Red gram

Sann hemp

Kesari

Black gram

Green gram

Cluster beans

Cowpeas

Other crops

Cotton (*Tellapathi*, G. *herbaceum*)

Gingelli

Deccan hemp

Jute

All the mixtures reported from different provinces are classified into those comprising one mixed crop with rice, those with two crops and those with more than two crops, and extracted below:

TABLE VIII

Mixture of rice

—	Cereals	Legumes	Others
With one crop	Rice (*aus* and *aman*) do. (othadam and *kuruvai*) do. (*virupu* and *mundakan*) Italian millet— *Jowar* *Bajri* Maize Kodo millet — *Panicum miliaceum*	Red gram *Kesari* Green gram Sannhemp	Cotton Gingelli Jute Deccan hemp
With two crops	Maize Maize *Jowar*	Green gram Field bean Red gram Red gram	Cotton
With more than two crops	*Kodo* millet do. do. *Jowar*	Red gram Red gram, cluster bean, cow peas	Gingelli and Deccan hemp Cotton Gingelli

It will be seen that the mixtures number 25 in all; in 14 of them there are cereals (one or more), in 10 there are pulses and in only 9 there are crops of other kinds. It will be also seen that 16 are two crop mixtures, 4 are three crops and 4 contain more. A curious mixture in which a large number of crops enter is one reported from the United Provinces, viz., rice with *jowar* (*Andropogon sorghum*), *til* (*Sesamum indicum*), *kakum* (*Setaria italica*), *patwa* (*Hibiscus cannabinis*) and *mandua* (*Eleusine coracana*). It need hardly be pointed out the rices referred to under these conditions are the hardy rices that can grow under dryland conditions and in the higher situations which will permit the growing of the associated dryland crops. The sowing is in lines of pure crops, or of mixed crops or broadcast as a mixture. It is also obvious that many of the crops will be ready for picking or harvest about the same time as the rice and considerable selective picking or harvest involving manual labour will be necessary, if the knocking about, shedding or outer damage and loss of crop is to be avoided. On the whole it would appear that rice is so grown under

these conditions principally with the object of affording to the dryland farmer a certain amount of rice, however small the quantity or however inferior the quality. The crop season is mainly the *kharif*.

Proportions—The proportion of the Kuruvai to the Ottadam in this mixed cropping in Tanjore is reported as 4 : 1. In the Godavari Delta experiments have been conducted with three different proportions, viz., 1 : 1, 1½ : 1, and 2 : 1 of the early crop to the late crop seed. The results showed that in all the three the total yields were uniformly the same. The yield of the early crop increased with the proportion of the seed from 1 to 2, but the yield of the late crop came down proportionately, thus making the total almost the same. The proportion of *aus* to *aman* in parts of Bengal where the mixture of these is grown, is given as 45 lb. of *aus* and 35 lb. of *aman* per acre.

Coming to the sowing of other crops in mixture with rice which is confined to dryland conditions information relating to the proportion of rice to the mixed crop in two crop mixture is extracted below : (further information will be found in the statements appended).

Cereals

Rice with *varagu*—3 : 2
do. maize—5 : 1
do. *jowar*—19 : 1, 30 : 1
do. Italian millet—6 : 4

Pulses

Rice with red gram—5 : 1, 8 : 1, 7 : 1, 2 : 1, 10 : 1
do. black gram—3 : 1

Other crops

Rice with cotton—4 : 1
do. Deccan hemp—2 : 1
do. gingelli—2 : 1

The proportions are all of seeds by weight.

Jowar

As a dryland food crop jowar occupies a pre-eminent place just as rice does as a wetland crop. It is grown as a food crop and also forms the bulk of the fodder ; it furnishes important green fodder also, and many varieties are grown extensively solely for this purpose. It is grown as a rainfed crop and as a semi-irrigated garden crop. It is grown both in the *kharif* season and in the *rabi* season, there being varieties suited to the two seasons. It is grown on a wide variety of soils, which are quite distinct from each other like the black cotton soils, the Gangetic alluviums and the red laterctic loams and on light soils and heavy soils, black, red and ash coloured.

The total rainfall however sets a limit to the tracts where it can be grown, the heavy rainfall tracts of the ghat sections of the peninsular India, on both sides of the Western Ghats, of Eastern Bengal and Assam being unsuitable for the crop, nor the heavy North East monsoon season in the coastal districts of the east coast. In the main or *kharif* season the rainfall of the South West monsoon is too heavy for the crop in districts of the west coast and on the plateaus adjoining the Western Ghats on its eastern side.

Crops mixed with jowar. As in the case of other crops, so in the case of *jowar* also, it is not possible to say to what extent it is grown pure and to what extent it is grown mixed. Though there are many conditions and tracts where it is grown without any mixture at all, still the bulk of the crop throughout the country appears to be grown only along with a mixture of one or more of other crops.

As in the case of rice, *jowar* itself of two varieties constitutes a mixture. Thus varieties of fodder *jowar* are sown as mixtures with the food grain *jowar*, either in lines within the field alternating with a much larger number of lines of grain *jowar* or all round as a border crop. These fodder *jowar* varieties afford considerable green fodder in the season, for which purpose indeed they are thus grown. The following crops numbering some 34 in all are grown in mixture with *jowar*.

Cereals

Rice
Bajri
Italian millet
Maize
Varagu (*Panicum miliare*)
Kuduravali (*Panicum crusgalli*)
Wheat

Pulses

Red gram
Black gram
Cluster beans
Methi (*Trigonella foenum graescum*)
Gram
Matki
Horse gram
Sann hemp
Cowpeas
Green gram
Field beans

Other crops

Castor
Linseed
Safflower
Gingelli
Groundnut
Cotton
Mustard
Pundi (*Hibiscus cannabinus*)
Coriander
Indigo
Cucumber
Water melon
Vegetables like brinjals, *bhendi*, etc.

The mixtures sown comprise two crops or three crops or more than three. In Table IX all the different mixtures reported as prevalent in the country are given in a classified form under the above divisions.

TABLE IX

Mixtures of jowar

——	Cereals	Legumes	Others
With one crop	Rice *Bajri* Maize Italian millet *Panicum miliaceum*	Red gram Field bean Green gram Black gram *Matki* Horse gram Bengal gram Cluster bean *Methi* Sannhemp Groundnut	Castor Linseed Safflower Deccan hemp Mustard. Cotton Coriander Indigo Cucumber Gingelli
With two crops	 *Bajri* Wheat *Bajri*	Cluster beans Cluster beans *Bajri* Maize Red gram Groundnuts Groundnuts Horse gram Red gram	Italian millet Castor Mustard Gingelli Cotton Jute

TABLE XI—*contd.*

Mixture of Jowar—contd.

——	Cereals	Legumes	Others
		Green gram and *matki*	
		Red gram and green gram	
		Cluster beans and *matki*	
		Groundnuts and field beans	
		Bengal gram	Safflower
		Red gram	Gingelli
		Black gram and cowpeas	
		Red gram and field beans	
		Field beans and cowpeas	
		Field beans and black gram	
With more than two crops	Italian millet	Cluster beans and cowpeas	
	Bajri	Cluster beans and black gram	
	Bajri	Cowpeas and groundnuts	
	Wheat		Safflower, linseed vegetables
	Jowar	Red gram and *matki*	
	Bajri		Cotton and gingeli
	Bajri		
		Red gram and black gram	
		Sannhemp and cowpeas	
	Sanwa millet, *kudo* millet and red gram		
		Cluster beans, black gram and Green gram	
		Red gram, black gram	Deccan hemp
		Redgram, *matki*	
		Black gram and cowpeas	
		Cowpeas, black gram	Deccan hemp
		Cowpeas, field beans and *matki*	
		Cowpeas, black gram	Gingelli

It will be seen that the different mixtures listed number as many as 60 altogether, out of these the largest number, viz., 41 contain one or more pulse crops, 19 contain one or more cereals and 22 contain one or more of the many other crops mentioned. The mixtures are thus largely food crop elements comprising *jowar* as the main grain crop and a few subordinate food grain crops and a large number of pulse crops, not to mention the vegetable crops in addition. The crops other than food crops comprise those which supply the domestic needs of the farmer such as Deccan hemp, the fibre crop, the oil seeds, gingelli and castor, while the others like linseed, coriander, groundnut and others may be regarded as both money crops and as being grown for domestic needs. The *jowar* field especially in the black cotton soil tracts and during the *kharif* season may indeed be regarded almost as self-contained store houses furnishing the farmer with nearly all his main requirements.

Proportions of the components –In common with the other crops, both major and minor, *jowar* enters into mixture with other crops, whether it be two crop mixtures

or mixtures with more than two crops, in a number of different proportions. This indeed is a remarkable feature of mixed cropping. It is not as if any one particular proportion has been found to be the most advantageous either from the economic or the scientific point of view, in which case this particular proportion will be adopted solely or in a very prominent degree. The very large and striking variations in the proportions would appear to indicate that the individual needs or convenience of the farmer or other varying causes decide the proportion rather than any definite economic or other factor. In cases where certain proportions predominate, the habit of growth of the mixed crop such as that of red gram or field bean or cotton as distinguished from that of the grain crops like *ragi*, *jowar*, *bajri* or Italian millet, and the extent to which such habit would permit of the mixture without unduly suppressing the growth of either kind has apparently been the deciding factor. Ratios decided by this factor form the basic ratios, so to speak, and have become the customary ratios in the tracts concerned, and the numerous variations from these ratios have been due to the convenience or temporary needs of the farmer.

It would appear that in certain provinces (the C. P. and Berars, for example), certain definite proportions have been 'fixed' — (it is not known if this has been done by Government or only the custom of the villages) and that a similar state of affairs prevails in many other parts of the country as well. Alterations have been introduced as the result of the war and the prevailing scarcity of food grains, which increase the proportion of the grain crop in the mixture. Thus if three rows of *jowar* are usually mixed with one row of red gram, this is altered into six rows of *jowar* and one of red gram ; likewise if five rows of Italian millet are usually grown with one row of cotton, the former is increased to ten or more rows to one of cotton, thereby increasing the area twice or more. As a matter of fact this is what the cultivator himself has been generally doing in order to adapt the proportion to changing needs.

In this summary, it is not possible to give the proportions in the case of all the three different classes of mixtures. We confine the propotions therefore only to those mixtures in which one other crop is grown in mixture with *jowar*. The proportions in which *jowar* and one other crop are grown together are as below :

Cereals

Jowar to Italian millet, 3 : 1, 1 : 40, 1 : 12
,, *bajri*, 1 : 12, 1 : 1, 2 : 1, 3 : 1, 4 : 1, and up to 8 : 1, 40 : 1
,, *kodo* millet, 3 : 1
,, *Panicum miliaceum*, 1 : 5

Legumes

Jowar to red gram, 1 : 1, 2 : 1, 3 : 1, 4 : 1, 5 : 1, 6 : 1, 7 : 4, 10 : 1, 17 : 3
,, field beans, 3 : 1, 4 : 1, 10 : 1

Jowar to black gram, 1 : 1, 2 : 1, 3 : 1, 4 : 1, 5 : 1, 5 : 3, 5 : 4, 12 : 5, 17 : 3
„ green gram, 1 : 1, 3 : 1, 4 : 1, 6 : 1, 10 : 1, 12 : 1, 17 : 3, 5 : 3
„ Bengal gram, 4 : 1, 5 : 1
„ horse gram, 1 : 1, 2 : 1, 3 : 1
„ cowpeas, 1 : 1, 2 : 1, 3 : 1
„ cluster beans, 1 : 1, 2 : 1, 3 : 1, 4 : 1, 5 : 1
„ *matki*, 1 : 1, 2 : 1, 3 : 1, 4 : 1, 6 : 1, 4 : 5, 15 : 1, 20 : 1
„ groundnuts, 1 : 5 and up to 1 : 15, 1 : 28
„ sannhemp, 4 : 5, 3 : 1
„ indigo, 5 : 2
„ *methi*, 15 : 2

Others

Jowar to cotton, 1 : 9, 1 : 1, 1 : 4, 3 : 8
„ *gingelli*, 12 : 1, 9 : 1
„ safflower, 3 : 1, 5 : 1, 8 : 1
„ castor, 3 : 1
„ Deccan hemp, 6 : 1, 19 : 1
„ mustard, 3 : 1
„ water melons, 2 : 1, 50 : 1

The proportions given are the proportions of the seeds by weight.

Bajri

Bajri is one of the major grain crops of India. It is grown throughout the country with the notable exceptions however of Bengal, Bihar and Assam among the important provinces. It is a grain crop almost exclusively of the *kharif* season, and is largely a rainfed crop. It is grown mostly on the red, loams and sandy loams, of the large stretches of the Gangetic alluvium ; the coarser and somewhat poor soils are put under this crop. Black cotton soils and heavy soils, and the deeper and better class soils generally are exceptional and are generally reserved for *jowar* and wheat. Even when the black cotton soils are sown with this crop it is only the medium and lower grades, light in colour and of little depth that are given over to *bajri*. Though mainly a rainfed crop, irrigation is also practised, especially in the Punjab.

The crops grown in mixture with *bajri* numbering 20 in all are the following :

Cereals

Ragi
Italian millet
Maize
Jowar (principally as fodder)

Pulses
- Red gram
- Black grem
- Field beans
- Green gram
- Horsegram
- Cowpeas
- Cluster beans
- *Matki*
- Sannhemp

Others
- Castor
- Gingelli
- Groundnut
- Indigo
- Gingelli
- Cotton
- Water melons

The absence of the following from the list of mixed crops is worthy of note thus rice, kodo millet, *Panicum miliare*, *Panicum miliaceum* among the cereals, Bengal gram among the pulses and among the crops of other categories the crops of the mustard group.

The exclusion is due to the seasonal unsuitability in some but in other it cannot be said whether it is a case of incompatibility and if so what the reason may be.

The mixtures consist as in the case of the others of either single crop or two crops or more crops. The Table X gives the information classified according to their number and composition :

TABLE X

Mixtures of ragi

—	Cereals	Legumes	Others
With one crop	*Jowar* do. (fodder) Maize Italian millet *Ragi*	*Matki* Horse gram Red gram Cluster beans Black gram Green gram Cowpeas Sannhemp	Cotton Ground nuts Gingelli Deccan hemp Water melons

TABLE X—*contd.*

Mixtures of ragi—contd.

——	Cereals	Legumes	Others
With two crops	*Jowar*	Red gram	
	Italian millet	Groundnuts	
	Jowar	Groundnuts	
		Red gram	Castor
		Green gram and black gram	
		Green gram and *matki*	
		Black gram and clusterbeans	
		Red gram and groundnuts	
		Cowpeas	Deccan hemp
		Cowpeas	Indigo
With more than two crops	*Jowar*	Red gram, groundnuts	
		Red gram, cowpeas	
			Cotton, gingelli
		Red gram, green gram, sannhemp, cow peas	Deccan hemp, cucumber
		Field beans, cowpeas	
	Ragi		
		Red gram, black gram, *Matki*, cow peas	Gingelli
		Red gram, cluster beans, black gram, green gram	
		Black gram, green gram, cow peas	
		Horse gram, *matki*, black gram	
		Red gram, green gram, cowpeas, *matki*	
		Cluster beans, black gram, *matki*	

The mixtures reported from the different provinces number 39 in all, cereals enter into 13, pulses into 29, and other crops into 11 mixtures.

Proportion of the components, Where mixtures are composed of *bajri* and one other crop, the proportion of *bajri* to the latter vary a good deal, and the range of these variations is as given below :

(*a*) *Cereals. Bajri* and *jowar* are as from 1 : 1 to 1 : 8, and also 12 : 1 mostly as fodder *jowar* in the Punjab. *Bajri* to Italian millet varies from 1 : 3 to 1 : 10 (Madras).

(*b*) *Pulses.* A large variety of pulses is grown with *bajri*, and in many parts of the country the pulses are mixed together and sown in the rows ; in parts of Bombay both pulses and *bajri* are mixed and sown in rows. Taking only such pulses as are grown as single crops with *bajri*, red gram is the commonest and the proportions are *bajri* to red gram is as 1 : 1 and 1 : 2 (Madras), 5 : 1 and 2 : 1 (Hyderabad), 5 : 1 (Bombay) and 1 : 1, 2 : 1, 3 : 1 and 4 : 1 (U. P.). *Bajri* with green gram varies in proportions from 1 : 1 to 4 : 1 ; with black gram from 1 : 1 to 1 : 8, and in one case is as 3 : 1 (U. P.). *Bajri* with cowpeas is as 3 : 1 and as 10 : 7, with *matki* as 1 : 1, 1 : 10, 5 : 1 and 4 : 3, and with karum *payaru* as 1 : 1.

(*c*) *Other crops.* These consist of groundnut, gingelli, cotton and Deccan hemp (*gogu*) ; and the respective proportions are as below :

Bajri with groundnut—1 : 26 (Madras)
do. gingelli—3 : 1 (Madras), 5 : 1 and 7 : 3 (U. P.)
do. cotton—4 : 1 and 2 : 1 (Madras and Punjab)
do. Deccanhemp —4 : 1 (Madras)

The proportions are all of seeds by weight.

Ragi

This grain crop is almost entirely a South Indian crop and is confined to the Madras Province and the Mysore State. To a very small extent it is cultivated also in the Bombay Presidency, Hyderabad, Bihar and in the Rajputana States.

It is a typically red soil crop, the red and light red loams characteristic of the most parts of Southern India form the most important if not the only soils on which it is grown. The crop can and sometimes is grown on the black cotton soils and on the black somewhat clayey soils under tank irrigation, but compared with the red soil cultivation, these are negligible.

The crop is confined to the *kharif* season and in the Mysore State where it is a very important crop and forms the staple food crop of the bulk of the people, it is grown almost entirely as a rainfed crop. In the Madras Province very extensively (if not universally) and in Mysore to a small extent, it is grown under irrigation.

As a rainfed crop in Mysore it is grown almost invariably with one or more mixed crops, though there are exceptions, such as where it is transplanted or in the case of the early sown crops. In Madras however even under irrigated cultivation, and also irrespective of the method of cultivation, broad-cast of transplanted, mixtures are almost the rule, and a very large number of crops are made use of for this purpose.

The crops which are grown in mixture with *ragi* numbering 24 in all are the following :

Cereals
- Wheat
- Italian millet
- *Jowar*
- *Panicum crusgalli*
- Maize
- *Save* (*Panicum miliare*)
- *Bajri*

Pulses
- Red gram
- Field bean

Black gram
Green gram
Horse gram
Sannhemp
Cowpeas

Others

Castor
Niger
Groundnut
Gingelli
Linseed
Deccan hemp
Mustard
Cotton
Amaranthus
Vegetables

The large variety of crops grown in mixture with *ragi* is noteworthy. The reason is principally the great importance of the crop as a food crop and the fact that nearly every cultivator grows it in the tracts concerned. The large variety of crops required in addition for the domestic use or petty trade of each person is therefore raised along with this food crop. Even where the main crop is groundnut or cotton, the importance of the *ragi* crop induces the grower to cultivate a little *ragi* also, even though it may be only a small percentage with the main crop.

This large variety of mixed crops, it will be seen, includes cereals, pulses, oilseeds, fibre crops, and vegetables, includes shallow-rooted crops and deep-rooted crops, short bushy low growing crops, tall and very deep-rooted crops, crops of short duration maturing before or simultaneously with *ragi*, crops of long duration maturing some two or three months after the *ragi*, tall crops with little or no branching and tall many branched bushy crops with a deep root system. Some of the crops are also such that they can flourish and make use of the heavy dews of the months of December and January, while the deep-rooted ones can thrive with the soil moisture in the deeper layers. The *ragi* crop itself is remarkably drought resisting and has the property of recovering from a long spell of drought in a striking manner, all of which are factors in making it a suitable crop in mixed cropping.

It will be seen that among the pulses Bengal gram does not figure, nor the oilseeds, linseed and safflower, cotton too is somewhat exceptional. These are crops pre-eminently of the black cotton soil, and partly also of the *rabi* or late season, which features will explain their exclusion. It cannot be said if they are incompatible with *ragi* and if so what the reason may be. On the whole *ragi* may be said to possess a wide range of compatibility.

The mixtures with *ragi* consist of single crops or of more crops. In the Table XI all the mixtures reported are classified into three classes, those with one, with two and with more than two crops with *ragi*.

TABLE XI

Mixtures of ragi

——	Cereals	Legumes	Others
With one crop	Wheat Italian millet *Panicum crusgalli* Maize *Jowar*	Red gram Field bean Black gram Green gram Horse gram Cowpeas Groundnuts Sannhemp	Cotton Mustard Niger Castor Gingelli Deccan hemp Amarnthus
With two crops	*Jowar*	Field beans Cowpeas and field beans Red gram Sannhemp	 Deccan hemp Gingelli Cotton and castor
With more than two crops	*Bajri* *Jowar*, rice and Italian millet	Field beans and cowpeas Black gram, red gram	Deccan hemp Castor Deccan hemp and vegetables

The total number of mixtures reported amount to 27 in all. Of these cereal enter into nine mixtures, pulses into 13 and other crops into 13 mixtures.

Proportions in mixtures—In most of the mixtures *ragi* is the main crop and therefore occupies the larger portion of the area. Even where the *ragi* comes in as a subordinate crop as in the case of groundnuts it occupies a larger area than may be considered usual in such cases. Taking the mixtures composed of *ragi* with one other crop the following proportions are reported :

(*a*) *Cereals*

Ragi with *jowar*, 70 : 30
do. Italian millet, 1 : 2
do. Wheat 3 : 1
do. ooda (*Panicum crusgalli*) 6 : 1

(*b*) *Pulses*

Ragi with field beans 12 : 1, 6 : 1, 4 : 1, 4 : 1
do. redgram 5 : 2, 4 : 2, 4 : 3, 5 : 3

Ragi with green gram 6 : 1
do. black gram 3 : 1, 6 : 1, 2 : 1
do. horse gram 6 : 1
do. cow peas, 3 : 1, 6 : 1, 4 : 1, 5 : 1
do. sann hemp, 6 : 1

(*c*) *Other crops*

Ragi with cotton, 3 : 2, 1 : 2
do. castor, 4 : 3
do. gingelli, 3 : 1
do. linseed, 5 : 1
do. ground-nut, 3 : 40, 1 : 38
do. indigo, 3 : 1
do. niger, 12 : 1
do. mustard, 16 : 1
do. Deccan hemp, 6 : 1

The proportions are all of seeds by weight.

For proportions in mixtures of more than crop with *ragi vide* appendix.

The crop it will be seen is grown both as a main crop as well as a subsidiary crop, however small this may be, and with almost every kind of crop. Thus while as a main crop it may occupy 12 or even 16 rows for every one row of a mixed crop, it may itself as a subordinate crop occupy only one row out of 40 rows as in the case of ground-nuts.

Wheat

Wheat forms an important cereal crop only in North India and in Peninsular India north of the river Krishna. The cultivation is confined to the *rabi* season, but in respect of soils there is a large variety such as the black cotton soils of different grades, the light and heavy loams of the Gangetic alluvium and fertile garden loams. The crop is grown both as a dry or rainfed crop and also under irrigation. The crops which are mixed with it are various ; they differ according as the wheat is grown on black cotton soils as a dry crop or the light and heavy loams under irrigation. These crops numbering 12 in all consist of the following :

Cereals
Barley
Jowar
Coarse rice (*sathri*)
Ragi
Pulses
Gram (Bengal gram)
Wild peas

Others
Mustard
Rape
Sarson
Turnips
Safflower
Linseed

It will be seen that as compared with other main crops wheat has only a small number of mixed crops. The fact that the season viz., *rabi*, is short as compared with the *kharif* and that the hot weather follows upon it closely, with its intense drying action upon the soil moisture, only crops of short duration, practically about 100 days or less, can be grown.

Among the mixed crops listed above, barley is the most important among cereals and the others, viz., *ragi*, rice and *jowar* are of very minor importance. Likewise among the pulses, gram is not only the commonest and the most important but is almost the only pulse crop mixed with it. Among the other crops linseed is the most important one with safflower as a very minor crop, except in parts of Bombay and Hyderabad; the mustard and its allied crops are very common and almost invariable mixtures, prevalent throughout Upper India from the N. W. F. Province in the west to Assam in the east.

The various mixtures classified according as they contain one crop, two crops and more than two, along with wheat are given below:

TABLE XII

Mixtures of wheat

——	Cereals	Legumes	Others
With one crop	Barley *Jowar* *Ragi* *Sathri* (coarse rice)	Bengal gram Wild peas	Linseed Safflower Rape Mustard Turnips
With two crops	Barley Barley Barley	Bengal gram Bengal gram Bengal gram Bengal gram	 Mustard Rape Linseed Mustard Rape
With more than two crops	Barley *Ragi*, Italian millet	Bengal gram Bengal gram Bengal gram	Mustard Onions and Cambodia cotton Mustard and safflower Linseed and mustard

The total number of mixtures reported amounts to only 21 on the whole, of these 9 contain cereals, 9 contain pulses and 14 contain crops of other kinds.

Proportions in mixtures. The proportion of the components in the crop mixtures which contain wheat and one other crop does not show the same very wide variation as in the case of other main crops. The barley and gram form important components in these two crop mixtures. The following are the proportions in respect of these crop mixtures :

Cereals

Wheat to barley, 1 : 1, 2 : 1, 3 : 1, 4 : 1, and 6 : 1

Pulses

Wheat to gram, 1 : 1, 2 : 1, 10 : 1 (Hyderabad)
1 : 1, 1 : $1\frac{1}{2}$, 1 : 2 (Bengal)
1 : 1, 2 : 1, 3 : 1, 4 : 1 (Punjab)
1 : 1, 2 : 1 (Assam)
4 : 3 (Bhopal)
1 : 4 (Bombay)
1 : 1 to 6 : 1 (in the U. P.)

do. berseem, 1 : 1

do. safflower, 10 : 1, 15 : 1, 6 : 1 and 7 : 1

Other crops

Wheat to linseed 9 : 1 and 15 : 1 (U. P.)

do. mustard and allied crops. 1 : 1, 4 : 1, 10 : 1, 40 : 1, 50 : 1 and even insignificant ones like 170 : 1 and 240 : 1

The proportions are all of seeds by weight.

Barley

Barley is an important grain crop only in the region north of the Vindhya mountains in the great Gangetic plains of Upper India. The United Provinces are the most important in this respect and the Punjab, North West Frontier Province, and Bihar come next while in Bengal and Assam it figures to a moderate extent.

Barley is a crop of the *rabi* season like wheat. With regard to soils the great bulk are the light loams, unlike wheat which is very important on the heavy black cotton type of soils, though to a large extent it is grown on the light loams also like barley. The crops which are grown as mixed crops with barley are not very numerous, which is rather noteworthy, as compared to other crops. The crops which form mixtures with barley numbering 14 in all are the following :

Cereals

Wheat

Pulses

Red gram
Bengal gram

Pulses—contd.
Lentils
Peas
Berseem, *shaftal*
Senji
Other crops
Linseed
Mustard
Rape
Sarson
Cereal

It will be seen that wheat is the only cereal crop grown with it, that the large number of minor pulses which usually comprise a pulse mixture green gram, black gram, cow peas, *matki*, etc., are absent. Lentils and peas which are practically Upper Indian crops are the pulses grown in addition to red gram and Bengal gram. As compared with wheat it is to be noted that red gram is grown with barley while it is not seen in any of the wheat mixtures.

Among the crops other than the cereals and pulses, there is a striking lack of variety, linseed and the different mustards being the only two kinds grown. On the whole barley is peculiar in the fact that so few crops enter into mixtures with it.

In the Table XIII, the mixtures are classified into mixtures comprising one crop, two crops and more than two crops with barley :

TABLE XIII

Mixtures of barley

——	Cereals	Legumes	Others
With one crop	Wheat	Red gram	Mustard
		Bengal gram	Linseed
		Lentils	*Sarson*
		Peas	
		Berseem	
		Shaftal	
		Senji	
With two crops	Wheat	Bengal gram	*Sarson*
		Peas and Lentils	
		Peas, Bengal gram	Mustard
		Peas, Bengal gram	Mustard and linseed
			Mustard
	Wheat	Lentils	Rape
	Wheat	Lentils	Mustard
		Bengal gram	Rape
With more than two crops	Wheat	Bengal gram	*Sarson*
	Wheat	Peas, Lentils	Mustard
		Peas, Bengal gram	Mustard and linseed

The total number of mixtures reported amount to 16 in all. Out of these five mixtures contain cereals either singly or in mixture, 13 contain pulses, and 10 contain the others, either singly or in mixture.

Proportions of the components. The proportions of the components in the mixtures in which one other crop forms the mixture with barley are as shown below :

Cereals

Barley to wheat 1 : 1, 1 : 2, 1 : 3, 1 : 6, 6 : 5, 9 : 1

Legumes

Barley to Bengal gram, 1 : 1, 1 : 3, 2 : 3, 2 : 1, 3 : 1, 7 : 3, 15 : 1

do. lentils 1 : 1, 2 : 1, 3 : 1, 6 : 1, 17 : 1, 1 : 1, 99 : 1, 2 : 3 (1 : 1 is very common in U. P.).

do. peas, 1 : 1, 1 : 2, 2 : 1, 3 : 1, 4 : 3, 3 : 2

do. *senji*, 1 : 1, 1 : 5

do. *shaftal* 1 : 1

Others

Barley to *sarson* or mustard 9 : 1, 49 : 1, 50 : 1, 40 : 1

do. linseed, 10 : 1

The proportions are of seeds by weight.

Maize

As an important grain crop grown on a field scale maize assumes much importance only in Upper India : the Punjab, the North West Frontier Province, North Bihar, Bengal and Assam may be taken as the main areas of cultivation on a large scale ; elsewhere it is more or less a garden crop of minor importance. The crop is grown as a mixed crop both as a rainfed crop and under irrigation. It is grown both in the *kharif* and in the *rabi* season. The crops which are grown in mixture with maize numbering 26 in all are the following :

Cereals

Rice (dryland)

Bajri

Italian millet

Sanwak (*Panicum colonum*)

Ragi

Jowar

Pulses

Green gram

Matki

Pulses—contd.
Cow peas
Matikalai
Red gram
Cluster beans
Berseem (*shaftal*)
Soyabeans

Other crops
Sarson
Turnips
Cotton
Castor
Sugarcane
Potatoes
Gingelli
Jute
Ground-nuts
Vegetables

The important grain crops of Upper India, viz., wheat and barley are not listed among the mixed crops nor even *jowar*, except as a border crop, raised apparently for fodder purposes. Among the pulses horse gram is not listed and even Bengal gram figures only to a very small extent. Linseed the important *rabi* season oilseed crop is likewise conspicuous by it absence.

Proportions of the mixtures. Taking the case of the mixed crops which are grown as the only mixed crop with maize, the proportions of the mixtures are reported as follows :

Cereals
Maize to rice (dryland), 5 : 1
do. *ragi*, 1 : 1
do. Italian millet, 1 : 3
do. *bajra*, 6 : 1
do. sanwak, 16 : 1
do. *jowar*, 1: 3

Pulses
Maize to cow peas, 5 : 4, 4 : 1, 2 : 1
do. black gram (*mush*), 2 : 1, 1 : 1, 5 : 2, 3 : 1, 5 : 1
do. green gram (*mung*), 2 : 1

Maize to gram, 1 : 1
do. berseem, 12 : 1
do. cluster beans, 3 : 2
do. red gram, 2 : 1, 4 : 1
do. soyabeans, 1 : 4

Other crops

Maize to turnips, 18 : 1
do. *sarson*, 8 : 1, 1 : 1
do. sugarcane, 1 : 20
do. turmeric, 1 : 4
do. garlic, 1 : 1
do. ground-nuts, 1 : 1
do. cotton, 1 : 5, 3 : 4

The proportions are all of seeds by weight.

In the Table XIV. the mixtures are classified into mixtures of maize with one crop, two crops and with more than two crops.

TABLE XIV

Mixtures of maize

—	Cereals	Legumes	Others
With one crop	*Bajri* Rice *Jowar* *Ragi* Italian millet *Panicum colonum*	Black gram *Matki* Bengal gram Berseem Soya beans Cow peas Red gram Cluster beans	Cotton Sugarcane Garlic *Sarson* Turnips Turmeric Potatoes
With two crops	*Jowar* Rice	Red gram Black gram Red gram Red gram Black gram and green gram	 Cotton Gingelli
With more than two crops	Rice, *jowar* Italian millet do. Panicum crusgalli	Black gram Green gram Red gram Black gram, green gram and cow peas	Jute Melons Cotton and castor Mixed vegetables

The number of mixtures reported amounts to 32 in all. Of these 11 contain cereals, 17 contain pulses and 13 contain other crops.

Cotton

This most important crop next to food crops is grown practically throughout India, with however some notable exceptions. It does not figure among the crops reported from Bengal and the North West Frontier Province and in Bihar and Assam it appears to be of only very minor importance.

The typical so called black cotton soils form the large bulk of cotton soils, throughout the country except in the Gangetic plain where the alluvial loams which are the prevailing type are put under cotton also. In South India there is a certain amount of specific preference of the black cotton soils for the local cotton varieties and of the red, reddish loamy or coarse soils for the American cottons. One indigenous cotton however is generally grown on the red soil and even coarse gravelly soils, viz., the *roseum* cotton.

Cotton is grown largely as a rain fed crop. The bulk of the indigenous cotton is grown only on the black cotton soils, and on these soils the cotton is grown only as a rainfed crop. Practically all the South Indian grown American cotton which comprises a good deal of the Dharwar American cottons of Southern Bombay, Mysore and Madras is also grown as a rainfed crop. The Cambodia cotton of Madras is almost entirely grown under irrigation like a garden crop. In the Punjab and the United Provinces cotton both American and even local, is grown largely under irrigation.

Cotton is grown both as a pure crop and with mixtures of one or more crops. As in the case of all the other crops it is difficult to say what the respective proportions of pure and mixed cultivation may be. As in the case of soils and irrigation, there is a certain preference for one or other method according to the variety grown; the Dharwar American cottons in Mysore, Southern Bombay and some other tracts is grown mostly pure, while mixtures are largely practiced in these tracts only in the case of the local cottons. The case of the Cambodia cotton is however different, many minor garden crops and others being grown in mixture especially along the margins, water channels, etc. The crops which are grown in mixture with cotton numbering 22 in all are the following :

Cereals

Rice
Ragi
Italian millet
Bajri
Jowar
Maize
Kodo millet

Pulses
- Red gram
- Black gram
- Green gram
- Horse gram
- *Matki*
- Cow peas

Other crops
- Cotton (*desi* or American)
- Ground-nuts
- Gingelli
- Castor
- Deccan hemp
- Chillies
- *Bhendi*
- *Sarson*
- Melons

The crops which are conspicuous by their absence in the above list are wheat and barley among the cereals, Bengal gram among the pulses and linseed among the other crops. All these it will be noted are *rabi* season crops while cotton is *kharif* sown crop, though sometimes the sowing may be so late as to be almost at the beginning of *rabi*.

The mixed crops are sown either singly with cotton or two or more of them enter the mixture. The various mixtures reported are classified in the Table XV into mixtures containing one mixed crop, two mixed crops and those with more than two.

TABLE XV

Mixtures of cotton

—	Cereals	Legumes	Others
With one crop	*Ragi* Italian millet Rice *Bajri* Kodo millet *Jowar* Maize	Black gram Horse gram Cow peas Red gram Green gram Cluster beans Ground-nuts Sann hemp	Coriander Gingelli Chillies Safflower Deccan hemp Melons *Sarson* Cotton, *desi* and American *Niger* Castor *Bhendi*

TABLE XV—*contd.*

Mixtures of cotton—contd.

—	Cereals	Legumes.	Others.
With two crops	*Ragi*		Castor
	Rice	Red gram	
	Jowar	Horse gram	
		Ground-nuts	Gingelli
		Horse gram	*Niger*
		Cow peas and black gram	
		Black gram and green gram	
		Red gram and ground-nuts	
			Niger and Deccan hemp
			Gingelli and amarnt
With more than two crops	Italian millet, wheat		Coriander
	Ragi, wheat, Italian millet		Onions
	Jowar, bajri		Gingelli
	Jowar	Horse gram, cow peas	Deccan hemp
	Italian millet	Black gram	Gingelli and *tinda*
	Maize	Red gram	Castor
	Kodo millet	Red gram	Gingelli and Deccan hemp
	do. rice	Cluster beans, red gram and cow peas	
		Field beans, cow peas, ground-nuts	
		Red gram, black gram and green gram	Coriander
		Cluster beans, cow peas	Deccan hemp
		Black gram	
		Red gram, cluster bean and black gram	Gingelli, *tinda* and *bhendi*
		Black gram, green gram	Gingelli

The total number of mixtures reported comprise 51 in all, which is very much larger than the number of mixtures for many other crops. Among these 18 mixtures contain cereals, 26 contain pulses and 31 contain other crops also. Italian millet is perhaps the most important among the mixed crops with cotton.

Among the mixtures reported one of the most interesting is the mixture of *desi* (indigenous) and American cottons which is said to prevail in the Punjab. It is well known that the lack of purity in the cotton marketed in India is greatly condemned and much propaganda is carried on for ensuring such purity and the avoidance of all causes by which such mixture may arise. That this kind of mixed sowing should take place and be carried out as a recognised practice in that province show that, the advantages of mixed sowing whatever they may be sufficiently outweigh in the estimation of cultivators those of maintaining purity in the crop, as to induce them to prefer the former course. It is however possible that the cotton from the two different varieties is gathered separately; we have no information on this point.

Such a special effort appears highly improbable, if one may judge from the general attitude of the ryot in such matters.

Attention may be drawn in this connection to the same kind of practice of sowing two varieties or types, which is said to prevail in the Malwa plateau and to which reference has already been made. Experiments reported by Mr. K. Ramiah, Geneticist, show that from a financial point of view such mixing is a distinct advantage.

The proportions in which any one single crop forms a mixture with cotton are as shown below :

Cereals

Rice, 1 : 4, 2 : 1, 1 : 1, 35 : 20, 40 : 35

Ragi, 1 : 6, 1 : 2, 2 : 1

Italian millet, 1 : 2, 1 : 1, 10 : 1, 2 : 1, 1 : 3

Bajri, 1 : 2, 1 : 1

Jowar, 10 : 1, 4 : 1, 1 : 1

Maize, 4 : 3, 5 : 1, 1 : 1, 6 : 1

Pulses

Red gram, 2 : 1, 15 : 2, 6 : 1, 3 : 1, 9 : 1, 12 : 1, 1 : 1

Black gram, 7 : 3, 7 : 1, 5 : 1

Green gram, 8 : 3, 7 : 1, 4 : 1

Matki, 2 : 1, 3 : 2, 5 : 1, 8 : 1

Horse gram, 5 : 8, 4 : 1, 1 : 1, 2 : 1, 3 : 1

Other crops

Cotton (*desi* and American), 1 : 10 to 10 : 1

Ground nuts, 3 : 40, 1 : 6, 1 : 5, 1 : 7

Gingelli, 8 : 2, 8 : 3, 20 : 1, 12 : 1, 5 : 1

Castor, 9 : 1

Deccan hemp, 9 : 1, 9 : 5

Chillies, 1 : 3, 32 : 1, 1 : 1

Bhendi, 8 : 3

Sarson, 3 : 1, 32 : 1, 20 : 1

Melon, 8 : 1

The proportions are all of seeds by weight.

Ground-nuts

Ground-nuts may be said to be almost solely a South Indian crop, some what like *ragi* among the cereals. It must be also considered a comparatively newly introduced

crop and the large and striking extension in the cultivation of the crop is certainly a matter of recent development, due to the large and profitable export demand which has been steadily on the increase for the last 30 or 40 years, with the exception of the period of the great war. For this reason unlike the many other crops which have been under cultivation for centuries in the case of this crop the general vogue of mixed cropping appears to have been taken up rather slowly and tentatively. The crop is grown as a pure crop to a much larger extent than any of the other dry-land (rainfed) crops. Other characteristics of the crop are such that they may be said to be favourable for mixed cropping in some respects and not favourable in other respects.

Firstly, the crop is of a low growing habit, the main variety is indeed only a creeping plant, and practically hugs the ground. The other type, viz., the so-called erect varieties, do not grow more than nine inches or a foot in height. This low growing habit is favourable to the growing of mixed crops of almost all kinds, as all of them grow taller and clear of the ground-nut crop. Secondly, the erect varieties are short duration crops of about three months or even less, so that many crops taking a longer period to mature lend themselves to be grown in mixture. Thirdly, the spreading varieties are of long duration taking five months to mature and therefore lend themselves to have short duration crops growing in their midst as mixed crops. On the other hand the spreading varieties cover the ground so completely and so thickly, specially under favourable conditions of rainfall and cultivation and the nuts form all along under the vines that conditions for mixed cropping are not favourable ; considerations of a full and economical utilisation of the soil which weigh in favour of mixed cropping, therefore do not arise. As the result, it may be said that for mixed cropping the short duration erect varieties are preferred to the long season creeping varieties. In fact in Mysore, it is rare to see mixed crops in the midst of these latter types at all.

The groundnut crop is grown as a rainy season (*kharif*) crop. It is grown both as a rainfed crop and as an irrigated crop, the former of course forming the bulk. The crop is largely grown in the light, very light and good loamy soils, mostly of the red lateritic type and the deep alluvial type ; the black cotton soils are also utilised but not to the same extent

Crops grown in mixture. Where mixed cropping is adopted a very large number of crops are made use of for the purpose. They number 17 in all and consist of the following :

Cereals

Bajri

Jowar

Ragi

Italian Millet

Cereals—contd.
Maize
Rice
Pulses
Red gram
Field gram
Cow peas
Black gram
Green gram
Horse gram
Other crops
Gingelli
Cotton
Castor
Deccan hemp
Coriander

It will be noticed that the typical *rabi* crops do not figure, as may be expected. Further, quite a number of leguminous crops also enter into the mixture notwithstanding the fact that the ground-nut itself belongs to the same order and that the mixture of legume and legume is not common. Attention may also be drawn to th e fact that many crops with a low growing habit and some with a semi creeping habit also, like horse gram, green gram, black gram, coriander and cow peas and field bean also are made use of for mixtures. The domestic or other needs of individual cultivators apparently form a more important factor than considerations of strict suitability in deciding the choice of crops used for mixing.

In the Table XVI, the various mixtures are shown classified according as they contain one, two or more crops along with the ground-nuts.

TABLE XVI

Mixtures of ground-nuts

——	Cereals	Legumes	Others
With one crop	Italian millet *Ragi* *Bajri* Maize *Jowar*	Red gram Green gram Cow peas Horse gram	Gingelli Cotton Deccan hemp Castor Coriander
With two crops	*Jowar* *Jowar* *Bajri*	Field beans Red gram Red gram	

TABLE XVI—*contd.*

Mixtures of ground-nuts—contd.

——	Cereals	Legumes	Others
With two crops	*Bajri* and *jowar*		
	Maize	Black gram	
		Red gram	Gingelli
		Red gram and green gram	
		Red gram	Deccan hemp
			Castor and gingelli
With more than two crops	*Panicum crusgalli*	Field bean	Coriander
	Rice	Red gram, cow peas	Gingelli
	Rice	Red gram, cow peas	Castor
	Maize		Cotton and Deccan hemp
		Red gram, field bean	Castor

The total number of mixtures reported is 28. Out of these 14 have cereals 15 have pulses and 12 have the other crops also.

Proportion of crops in the mixture. The proportion in which the different crops are mixed in the mixtures which have only one mixed crop with ground-nuts are the following :

Cereals

Ragi, 80 : 6

Italian Millet, 70 : $2\frac{1}{2}$, 9 : 1

Bajri, 60 : 4, 10 : 2, 80 : 3, 80 : 4

Maize, 80 : 20

Pulses

Red gram 9 : 1, 70 : 1, 75 : 2, 60 : 4, 7 : 1, 10 : 1, 6 : 1, 50 : 3, 25 : 2, 8: 1, 3 : 1, 7 : 1

Green gram 10 : 2

Other crops

Cow peas, 60 : 1

Gingelli, 95 : 5

Castor, 5 : 1

Cotton, 40 : 3, 10 : 2, 7 : 1

Deccan hemp, 10 : 2, 25 : 1

Coriander, 15 : 1, 20 : 4

The proportions are all of seeds by weight.

RED GRAM

Red gram may be regarded as both distinctive and important among mixed crops. It is seldom or never grown pure except on a very small scale and mixed cropping may be said to be the rule on a field scale. It forms one of the most important and extensively grown pulse crops of the country. With the exception of the N.W.F. Province, the Panjab in the north and Assam in the east, in all other

parts of the country viz., Madras and Bombay Presidencies, the Central Provinces and Berar the U.P., Bihar and Bengal, the Central Indian States, Hyderabad, Mysore grow the crop extensively. The western parts of peninsular India where the S.W. monsoon is very heavy, as likewise the north-eastern province like Assam where the rainfall is equally heavy, do not grow the crop, on this account. It is not clear why the crop does not figure in the Punjab where the rainfall is low and where it is insufficient can be supplemented by irrigation. In tracts where rainfed cultivation is alone possible and the cultivation season is only the *rabi* or north-east monsoon season, the season is too short for the crop and Bengal gram takes its place as the staple pulse crop. Red gram as a mixed crop is also noteworthy because it is grown in mixture with a large number of crops and the combinations are numerous. In the regions of its cultivation it may be called a universal favourite consorting with advantage with every crop under general cultivation.

The crop is grown as a *kharif* crop, but it occupies the ground through part of the *rabi* season also ; the crop season extends from June-July to February-March.

It is grown on all the different kinds of soils, the red soils of South India, the black cotton soils, the Gangetic alluvium and even rough gravely soils.

It is grown in mixture with one single crop, with two or more than two, which may go up to even six in number. They comprise cereals, legumes and crops of other kinds, as given below :

Cereals

Rice (dry or upland)
Jowar
Bajri
Ragi
Italian millet
Kodo millet
Maize

Legumes

Black gram
Green gram
Field beans
Cluster beans
Matki
Cow peas
Sann hemp
Lentils
Ground-nuts

It will be noticed that the typical *rabi* crops like wheat, barley, Bengal gram, safflour, linseed, rape, mustard, etc. do not find a place in the list.

The total number of mixtures listed from the different provinces and States is 65 of these 17 contain only one crop together with red gram ; 22 contain two and 26 contain more than two. Moreover cereals enter into 41 mixtures, pulses in 36 and ; others in 32. These are tabulated in a classified form below :

TABLE XVII

Mixtures of red gram

—	Cereals	Legumes	Others
With one crop	Rice	Black gram	Deccan hemp
	Jowar	Green gram	Gingelli
	Bajri	Field beans	Cotton
	Ragi	Cow peas	
	Italian millet	Ground-nuts	
	Kodo millet		
	Maize		
	Panicum miliaceum		
	Panicum miliare		
With two crops	*Jowar*	Ground-nuts	
	Bajri	Ground-nuts	
	Jowar, bajri		
	Jowar	Field beans	
	Rice		Cotton
	Jowar		Gingelli
	Jowar		Jute
	Jowar	Black gram	
	Jowar, maize		
	Jowar, kodo millet		
	Jowar, rice		
	Jowar	Cluster beans	
	Maize		Gingelli
	Maize		Cotton
	Maize	Black gram	
	Kodo millet	Cow peas	
	Italian millet	Cow peas	
		Ground-nuts	Castor
		Ground-nuts	Deccan hemp
		Black gram and green gram	
		Black gram	Deccan hemp
		Black gram	Cotton
With more than two crops	*Jowar*	Field beans	Gingelli, castor
	Jowar	*Matki*, green gram, cow peas	
	Jowar	Black gram, green gram	
	Jowar	do. do.	Gingelli
	Jowar	Masoor	Gingelli
	Jowar	Black gram	do. Deccan hemp
	Jowar, rice, *ragi* and Italian millet		do. do.
	Jowar	Cluster beans	Cotton
	Bajri	*Matki*, cow-peas and green gram	
	Bajri, jowar	Green gram, sann hemp and cow peas	Cucumbers
	Bajri	Black gram, green gram	
	Bajri	Black gram	Gingelli
	Ragi	Black gram	Castor
	Ragi, rice	Ground-nuts	Gingelli, castor

TABLE XVII—*contd.*

Mixtures of red gram—contd.

——	Cereals	Legumes	Others
	Maize		Cotton, castor
	Maize, Italian millet and *Pan. miliare*		Jute
	Kodo millet		Castor gingelli
			Gingelli, Deccan
	do.		
		Black gram green gram	Gingelli
	do.	do.	Castor, *bhendi*
		do. cluster beans	Cotton
		do. green gram	Cotton, Deccan hemp and gingelli
		Black gram	Cotton, Deccan hemp
	Panicum miliaceum		Cotton castor

Proportions of Components.

The proportions in which the seeds of the different components are mixed are also very varied. They are perhaps more numerous than in the case of many other crops. These proportions are given below in respect of the mixtures which contain one other crop in addition to red gram. For other mixtures the statements in the appendix may be consulted.

Cereals

Red gram with rice 1:2, 1:4, 1:5, 1:6, 3:4, 2:1, 2:5, 1:7, 1:12, 3:25 ;
Jowar: 1:2, 1:4, 1:5, 1:10, 3:10
Bajri 1:8, 1:9, 1:1, 1:2, 1:3, 1:5, 1:50
Ragi 1:2 ;1:5, 1:6, 3:4, 2:1, 2:5
Italian millet 1:5, 1:7, 3:5 ;
Maize 1:3, 1:4
Kodo millet 5:1, 1:15
Panicum miliaceum 1:8, 1:9, 2:3
Panicum miliare 1:7

Legumes.

Red gram to black gram 2:3, 1:2
Green gram 1:7, 2:3
Field beans 3:7
Cow peas 5:7
Ground-nut 1:6, 1:7, 1:8, 1:15, 1:35, 1:60, 1:70

Others

Red gram with cotton 1:3, 1:5, 1:8, 1:9, 1:10, 1:14, 1:19, 3:44
Gingelli 1:1, 1:2, 1:3, 1:10, 7:9
Deccan hemp. 5:1, 9:5

The porportions given are of seeds by weight

Italian millet

Although as a rule the grain crops are mostly grown as main crops whether pure or with subordinate crops as mixture, the case of Italian millet is somewhat exceptional. It is grown more or less as a subordinate crop and in mixture with a main crop which is very often cotton. Where rainfall is favourable and the soil fertile and well prepared it is sometimes grown as a pure crop of the year ; under these conditions a better yielding variety in which the earheads are long and heavy and drooping with the weight of grain is grown and a good yield of grain is obtained. To grow it as a mixed crop is however the common practice and a hardier one though less yielding variety is chosen for this purpose, the chief advantage of mixed cropping viz., an insurance against bad seasons being secured thereby. The crop is largely grown in the Deccan and South India generally, although to a certain extent it figures in Upper India also.

It is grown on all kinds of soils, the red lateritic, the Gangetic alluvium and the black cotton soils, on which it is grown in mixture with cotton.

The season is kharif—

The crops with which it is grown in mixture number 21 and are the following :

Cereals

Rice
Jowar
Ragi
Bajri
Maize
Wheat
Panicum miliare

Legumes

Red gram
Black gram
Green gram
Groundnuts
Sann hemp
Cluster beans
Cow peas

Others

Cotton
Gingelli
Deccan hemp
Coriander
Onions
Castor
Niger

The mixtures are not large in number being only 20. They comprise as in the case of other crops those with one crop in addition to Italian millet, those with two and those with more than two. They are tabulated in a classified form in Table XVIII.

TABLE XVIII

Mixtures of Italian millet

—	Cereals	Legumes	Others
With one crop	Rice *Jowar* *Ragi* Maize	Red gram Black gram Green gram Ground nuts Sann hemp	Cotton
With two crops	*Jowar* *Jowar* *Bajri* Maize	 Cow peas	Castor Niger Gingelli Cotton, gingelli
With more than two crops	Wheat *Ragi* *Jowar* Maize and *Panicum miliare* Rice, *ragi* and *jowar*	 Cow peas, cluster beans Black gram Red gram	Cotton, coriander Cotton, onions Gingelli, Deccan hemp

Proportions. The proportions in which the components are mixed are as below (mixture with one crop in addition to Italian millet):

Cereals

Italian millet to rice 3 : 2
do. *jowar* 1 : 1, 1 : 3, 3 : 4, 40 : 1
do. *ragi* 1 : 2, 1 : 6
do. maize 3 : 1

Legumes

Italian millet to red gram 5 : 1, 2 : 1, 5 : 3
do. black gram 2 : 1
do. green gram 2 : 1
do. ground nuts 1 : 9, 1 : 5, 3 : 80
do. sann hemp 1 : 2

Others

cotton 1 : 2, 1 : 10, 2 : 5

The proportions are of seeds by weight.

In view of the shortage of grain during the last two years it has been attempted to raise the proportion of the Italian millet in the mixture and thereby to increase the acreage under the crop.

APPENDIX I

GLOSSARY OF VERNACULAR AND COMMON NAMES OF CROPS WITH THEIR BOTANICAL NAMES

Alu	*Colocasia antiquorum*
Ambadi	*Hibiscus cannabinus*
Arahar	*Cajanus indicus*
Arhar	,, ,,
Arika	*Paspalum scrobiculatum*
Avare	*Dolickos lab-lab*
Bajri	*Pennisetum typhoideum*
Bavto	*Eleusine coracana*
Barley	*Hordeum vulgare*
Bengal gram	*Cicer arietinum*
Berseem	*Trifolium alexandrinum*
Bhendi	*Hibiscus esculentis*
Black gram	*Phaseolus mungo*
Cambu	*Pennisetum typhoideum*
Castor	*Ricinus communis*
Chari	*Andropogon sorghum*
Chatri	*Lathyrus sativus*
Chuali	*Amaranthus blitum*
Chavali	*Cynamopsis psorialioides*
Cheema	*Panicum miliaceum*
Chillies	*Capsicum annuum*
Coriander	*Coriandrum sativa*
Cotton	*Gossypium* spp.
Cluster bean	*Cyampsis psorialioides*
Deccan hemp	*Hibiscus cannabinus*
Dhania	*Coriandrum sativa*
Ganti	*Pennisetum typhoideum*
Gingelli	*Sesamum indicum*
Gogu	*Hibiscus cannabinus*
Gowar guar; guara	*Cyampsis psorialioides*
Gram	*Cicer arietinum*
Ground-nuts	*Arachis hypogea*

Ginger	*Zingiber officinale*
Green gram	*Phaseolus radiatus*
Horse gram	*Dolichos biflorus*
Jodal	*Avena sativa*
Jola	*Andropogon sorghum*
Jonna	,, ,,
Jowar	,, ,,
Juar	,, ,,
Jute	*Corchorus capsularis, C. olitorius*
Kakum	*Setaria italica*
Kalai	*Phaseolus mungo*
Kali rai	*Brassica nigra*
Kamni	*Phaseolus aconitifolius*
Kangani, kangni	*Setaria italica*
Kasi mati-kalai	*Phaseolus calcalatus*
Kesari	*Lathyrus sativus*
Kodo, kodon	*Setaria italica*
Kodo millet	,,
Korra	,,
Kudrum	*Hibiscus cannabinus*
Kumra	*Cucurbitus* spp.
Kusum	*Carthamus tinctorius*
Kuthuraivali	*Panicum crusgalli,* var. *frumentaccum*
Lobia	*Vigna catiang*
Linseed	*Linum utitatissimum*
Maize	*Zea mays*
Mandua	*Eleusie coracana*
Marua	,, ,,
Mash	*Phaseolus radiatus*
Massoor	*Lens esculenta*
Massar	,, ,,
Matar	*Pisum sativum*
Matki	*Phaseolus aconitifolius*
Methi, Meth	*Trigonella foenum graecum*
Methra	,, ,,

Moth, Mothi	*Phaseolus aconitifolius*
Mong	*Phaseolus radiatus*
Mug	,, ,,
Mung	,, ,,
Mustard	*Brassica nigra*
Melon	*Cucurbita melo*
Navane	*Setaria italica*
Nagli	*Eleusine coracana*
Niger	*Guizotia abyssinica*
Okra	*Hibiscus esculentis*
Onion	*Allium cepa*
Ooda	*Panicum crusgalli*
Patal	*Trichosanthes dioica*
Patson	*Hibiscus cannabinus*
Patwa	,, ,,
Peas	*Pisum arvense*
Pillipesara	*Phaseolus aconitifolius*
Pundi	*Hibiscus cannabinus*
Ragi	*Eleusine coracana*
Rahar	*Cajanus indicus*
Rai	*Brassica juncea*
Rala	*Setaria italica*
Ramas	*Vigna catiang*
Ravan	,, ,,
Red gram	*Cajanus indicus*
Rice	*Oryza sativa*
Safflower	*Carthamus tinctorius*
Sajje, sajjalu	*Pennisetum typhoideum*
Sankukra	*Hibiscus cannabinus*
Sanai	*Crotalaria juncea*
Sann hemp	,, ,,
Sanwak	*Panicum colonum*
Sarson	*Brassica napis*
Sathra	*Oryza sativa*
Sawan	*Panicum frumentaceum*

Senji	*Mellilotus parviflora*
Shaftal	*Trifolium resupinatum*
Sheria	*Hibiscus cannabinus*
Sesamum	*Sesamum indicum*
Sugarcane	*Saccharum officinarum*
Suran	*Amorphophallus campanulatus*
Swank	*Panicum colonum*
Save	*Panicum miliare*
Taramira	*Eruca sativa*
Teora	*Lathyrus sativa*
Tenai	*Setaria italica*
Tinda	*Citrus vulgaris*
Togari	*Cajanus indicus*
Tori	*Brassica napus*
Tur	*Cajanus indicus*
Tuver	„ „
Turmeric	*Curcuma longa*
Urid, Urd, udid	*Phaseolus mungo*
Val	*Dolichos lab-lab.*
Variga	*Panicum miliacum*
Varagu	„ „
Wheat	*Triticum sativum*
Yam	*Dioscorea sativa*

APPENDIX II

SUMMARY OF RESULTS OF MIXED-CROPPING EXPERIMENTS IN MADRAS PRESIDENCY

Station	Components of the mixture	Results
Coimbatore (cotton breeding station)	Pulses in combination with sorghum in different proportions in three different soils (irrigated red, rainfed red and rainfed black)	The mixing of pulse with both irrigated and rainfed sorghums did not benefit either the sorghum or the succeeding cotton ; on the other hand mixing lowered the straw weight

Station	Components of the mixture	Results
Coimbatore	Cotton mixed with *setaria*, horsegram and Coriander	Pure Cotton best but of the mixtures, cotton and *setaria* combination best. With cotton at normal price it would not be profitable to grow any mixture, though the demand for grain and fodder may make it useful.
	Mixtures of lab-lab and castor compared with pure castor in rotation with sorghum	Castor best as pure crop
Guntur	Pillipeasara with sorghum for fodder	No increase in yield of fodder
	Cotton with groundnut and setaria	Cotton and groundnuts gave the best monetary return followed by cotton and *setaria*, pure cotton resulting in a loss
Hagari	Cotton and setaria . .	Earlier experiments showed mixture is more economical than cotton alone but subsequent experiment disproved this showing that pure cotton, is economically the best
	Pulses with setaria . . .	More economic than pure *setaria*. Of the pulses groundnut horse gram and *pillipesara*, groundnuts gave the best result
	Mixtures of sorghum and Bengal gram, sorghum and groundnut	Results not consistent
Kovilpatti	After-effects of a mixture (black gram and green gram in combination with sorghum) on the succeeding cotton	The harmful effects of sorghum not reduced by the mixed cropping
	Bengal gram, coriander and horse gram mixed with cotton	Monetary values of all the mixtures were less than that of pure cotton

Station	Components of the mixture	Results
Nandyal	*Pillepesara* with sorghum .	Depressing effect on the yield of sorghum. Pure sorghum best
	Sorghum with black gram, green gram and horse gram, cotton with horse gram	In the mixtures sorghum with horse gram the best combination. No difference in total outturn whether cotton grown pure or mixed with horse gram.
Palur	Groundnut inter-planted in a cereal	More advantageous than a groundnut-cereal rotation. Of the cereals, *ragi* proved to be best mixed with groundnuts.
		Change in the cereal had a better effect on the yields of groundnut and cereal than when the same cereal was repeated every year.
Tindivanam	Groundnut with *sorghum* cumbu, *setaria*, red gram castor	Monetary return was more from a mixed crop than pure groundnut crop, though the yield of groundnut was lower. Except *Setaria* or cumbu, all the others gave the better returns (monetary) than pure cropping.

APPENDIX III

SOME SELECTED ROTATIONS IN THE DIFFERENT PROVINCES

1. North West Frontier Province

1. Maize—wheat—maize
2. Rice—*shaftal*—maize
3. Maize—tobacco—maize
4. Wheat—fallow—wheat
5. Wheat—cotton—wheat
6. Maize—berseem—maize
7. Maize—fallow—maize

8. Maize—*moth*—wheat
9. Maize—lentil—maize
10. Peas—fallow—peas
11. Rice—wheat—rice
12. *Shaftal*—sugarcane (ratooned for three years)—wheat
13. Gram—*bajra*—gram
14. Gram—*bajra*—*toria*
15. Barley—fallow—gram
16. *Toria*—maize—*toria*, etc.

2. *Bihar-Bhagalpur Range*

For single cropped —' Diara ' and ' Chaur ' lands (inundated during rains) paddy land.

For double cropped.—

For single cropped—' Diara ' and ' Chaur ' which get flooded sometimes early in the season and sometimes late.

The cultivators generally put in a crop of maize or millets like *khari* and *chena* during the *kharif* if they get early rains. In years the floods are late they get a crop, otherwise the crop is destroyed. In *rabi* wheat, gram, barley, peas etc., are rarely grown singly.

In paddy lands, paddy is followed by paddy in next year. In favourable years and in a restricted number of plots, peas, linseed, or *khasari* are sown broadcast on the standing crop. In rare cases paddy plot is cultivated and a *rabi* crop is grown with irrigation.

Double cropped lands (not subject to innudation)

(*a*) Maize or *juar* (for fodder) followed by *rabi* cereals, pulses, oilseeds like mustard and linseed, tobacco and chillies. The local practice is to sow the *rabi* crop in mixtures.

(*b*) Maize and *jowar* sown with *rahar maize* and *jowar* is harvested in September October and *rahar* stands till March.

In Purnea District where jute is grown the rotations are :
Lowland jute followed by paddy or lowland jute — first year, second year paddy.
Because in many lowland jute plots the standing water remains so high after harvest that no transplantation is possible (small percentage of lands).

3. *Bhopal*

The general practice is to sow cotton or *jowar* after wheat, followed by gram.

4. *Bihar-Chota Nagpur Range*

It may be noted that these rotations are not rigidly adopted and mixed cropping is not very much in vouge in this tract.

PADDY LANDS

Kharif	*Rabi*
First year paddy broadcasted	Fallow or gram (*Cicer arietinum*) Wheat, moong (*Phaseolus mungo*) Linseed or *khesari lathyrus sativlus* as *paira* crop
Second year paddy transplated	do. do.

UPLANDS

Kharif	*Rabi*
First year— *Ragi* (*Eleusine coracana*) *Urid* (*Phaseolus eadiatus*) *Rahar* (*Cajanus indicus*)	Rahar and fallow
Second year—Paddy (*gora*), one of the early ripening variety	Fallow
Third year—*Urid*	Fallow
Fourth year— *Gundali* (small millets) *Kulthi* (*Dolichos biflorus*) *Surgura* (oilseed)	Fallow
First year—*Aus* paddy	Sugarcane
Second year—Sugarcane	Sugarcane

No definite rotations are followed in the case of maize, *jowar*, wheat, gram, barley, groundnut. They are grown in the same field year after year as follows :

(i) First year	Maize or *juar* with *sanai* or kudrum
(ii) First year—fallow or paddy	Wheat mixed with barley.
(iii) First year fallow or paddy	Gram mixed with barley and linseed
(iv) First year—groundnuts	Fallow

5. *Patna Range*

Paddy is the principal crop grown ; the most general rotation is :

Paddy—*kesari*, or *kesari* and linseed mixed, or gram sown in standing crop of paddy.

The area of land which does not grow paddy is comparatively small and is confined to upland or some medium land. On such land if irrigable the rotations are :

Maize or *marua* or fallows —Potato or other vegetables or chillies.

If such medium lands are not irrigable, the general rotation is maize and *rahar*—

Udid mixed wheat and gram or barley and gram.

6. *Tirhut Range*

Low land—Paddy land

Paddy is grown year after year in the same land, and no rotation is taken. But at places where water remains in the fields when the grains reach the milk stage broadcasted crops like gram, peas and *khasari* are taken in the paddy fields. In a few cases linseed is also broadcasted.

Uplands

	Kharif	*Rabi*
Rotation I—		
First year	Maize or mixture of millets	Sugarcane
Second year	Sugarcane	do.
Third year	Maize or fallow	Wheat
	or	
	Maize and *rahar* (mixed)	*Rahar*
	or	
	Maize, *rahar* and cotton (mixed)	*Rahar* and cotton
Rotation II—		
First year	Green manure (in sugarcane belt only)	Sugarcane
	Maize, *juar*, *ragi* or groundnut or fallow	do.
Second year	Sugarcane	Wheat, barley or gram or mixture of these
Third year	Fallow or maize	*Rahar*
	or maize and *rahar* mixed or early paddy	Green or gram and linseed mixed or peas or *rabi* cereales or cane
Rotation III—		
First year	Maize or *marua*	Wheat or barley or barley with gram and peas or gram with mustard and linseed
	or maize and *marua*, *rahar*	*Rahar*

	Kharif	*Rabi*
Second year	Fallow or pulse crop	Wheat alone or wheat and mustard or wheat and chillies or tobacco or potatoes
Third year	Fallow	
Fourth year	Maize	Wheat or barley alone or mixed with mustard, linseed

7.—Bengal Province—Northern Circle

Rajshahi District	*Kharif*	*Rabi*
First year	Jute	Transplanted *aman*, *khesari*, lentil, mustard, wheat, etc. (or any of the above crops)
	Sugarcane	Sugarcane
Second year	*Aus* paddy	Transplanted *aman*, *khesari*, lentil, mustard, wheat, etc. (or any of the above crops)
	Jute and sometimes *aus* paddy	do.

N.B.—In low land and *khear* tracts only *aman* paddy is grown where no rotation is followed

Dinajpur District

Aus paddy is followed by 1. *khesari* 2. barley 3. onion. *Aman* paddy is followed by 1. *aman* paddy 2. gram or lentil 3. mustard 4. English vegetables 5. *kali* 6. *aman paddy*

Pabna District

1. *Aus* or broadcast *aman* is followed by either of the following in the *rabi* season
   Wheat, pulses, sugarcane, or sannhemp for fibre
2. Sugarcane is followed by *aus* paddy or jute or *jowar*
3. In the low lying *char* land or on the banks of the river *aus* and broadcast paddy is followed by wheat, barley or pulses

Jalpaiguri District

1. *Aman* is grown year after year in the same land without any (*kharif*) rotation
2. *Aus* (*kharif*)—motihari tobacco (*rabi*) to a certain extent

3. Barley (*rabi*)—*aus* of jute or fallow (*kharif*)—motihari tobacco (*rabi*) followed a little
4. Jute (in *kharif*)—aman grown in the same season of the year in low land or motihari tobacco (in the *rabi* season in high land)
5. Tobacco, *bengi* variety (*rabi*)—fallow (*kharif*)—tobacco or in some land *kalai* (*rabi*)

Rangpur District

Paddy followed by wheat, potato, barley, *khesari*, etc. (one year rotation)

Bogra District

Sandy loamy tract or jute is followed by	Broadcast *aus* paddy potato	In *kharif* season do.
Pulses like *kalai* or		*Rabi* season
Pulses like *kalai* or lentil or wheat or barley		do.
Clayey low lying areas. Transplanted or deep water paddy or Sugarcane		*Kharif* and part of *rabi* *Kharif and rabi*
Transplanted paddy (in limited areas)		*Kharif* and part of *rabi*
Khesari or pulses	do.	*Rabi*

Darjeeling District

Maize is followed by *marua* or one of the pulses soya bean, *mashaym*, *kalai wrid*, *kulthi*, potato. When either of these is used it grows in its early stages in between the maize. Or, one of the following is grown after the harvest of maize barley, buckwheat *uwa* wheat, mustard or rape. After harvest of *aman* paddy either wheat, barley, buck wheat, or potato is grown.

Rotations in Assam

Being a pre-eminently paddy area, and as it is very difficult to grow any other substitute crop in the paddy fields, systematic rotations are unknown. On limited areas called sugarcane area, vegetable area, etc., the following are practised, viz., Sugarcane—ratoon—*aus* paddy and pulses—sannhemp and sugarcane. Jute land. Jute or *aus* paddy followed by pulses, oilseeds, potatoes and other vegetables. Vegetable area : *Colocasia antiquorum*—early *aus* paddy—potato, radish, brinjal, chillies, sweet potato, etc.

Panjab Province

Montgomery Circle. Irrigated tracts (1) Wheat—gram—wheat. (2) Wheat *toria*—cotton. (3) Wheat—maize—*senji*—sugarcane. (4) Rice-berseem-cotton.

(5) Rice-gram. (6) Rice-wheat. (7) Wheat-cotton-sugarcane. (8) Wheat-*kharif* fodders-gram. Rainfed areas. (1) Wheat-*bajri* or *jowar*. (2) *Bajri*-fallow-wheat. (3) Wheat-green gram and gingelli-fallow. (4) Wheat-gram.

Jullunder Circle. Kangra (1) Wheat-rice-green gram. (2) Wheat-linseed. Hoshiarpur under well irrigation (1) Tobacco-maize-potatoes. (2) Maize wheat-tobacco. (3) Cotton-*methi*-sugarcane-wheat. (4) Wheat-*jowar* and cluster beans or *jowar* alone.

Rainfed area. (1) Cotton-fallow-cotton. (2) Cotton-fallow or *jowar* and *matki*-cotton. (3) Wheat-maize. (4) Wheat or gram-*jowar*-cluster beans or *bajri*. (5) Wheatgreen gram and gingelli-fallow.

Sailab areas. (1) Rice-fallow-rice. (2) Wheat-rice. (3) Wheat-rice-*senji* or berseem-rice.

Jullunder and Ludhiana. (1) Wheat-maize-sugarcane-*senji*. (2) Wheat-*jowar*-and cluster beans-gram-cotton. (3) Tobacco-maize-potato. (4) Rice-wheat. (5) Maize wheat. (6) Maize-*senji*-tobacco.

Ferozepore. (1) Rice-gram. (2) *Jowar*-gram. (3) *Bajri*-cotton-wheat. (4) Maize-sugarcane-wheat. (5) Wheat-fodder crop-cotton.

Upper Assam Division. (1) *Ahoo* followed by mustard, pulses, wheat and potato, in the riparian tracts. (2) Sugarcane followed by jute or fallow. Lower Assam Valley. (1) *Aus*-mustard and lentils-*aus* or jute. (2) Wheat-*aus*-wheat. (3) *Aus*-pulse or mustard-*ahoo* or jute. (4) Sugarcane-ratoon-fallow-*aus*. (5) *Aman*-pulse aman. (6) Jute-mustard-*aus*-jute.

Central Provinces

In the Eastern districts of the province, on heavier *rabi* soils which are not bunded the rotation followed is :

First year. *Rabi* wheat, linseed or gram according to soil and moisture.

Second year. *Kharif* crop. *Kodo, rahar, til* mixture.

In bunded *rabi* fields a rotation of wheat, gram and linseed is followed.

In the Southern districts of the province, common crop rotations are as follows :

Main crop	Rotation crop	
	First year	Second year
Rice	This is generally not rotated Lakori, udid and sometimes linseed is taken as a utera crop on heavy soils only	
Jowar	Groundnut	Cotton
Bajri	Groundnut or *tur*	Cotton

Main crop	Rotation crop	
	First year	Second year
Wheat	Gram and pulse other crop	Linseed
Maize	Groundnut or *mug* or *udid*	*Tur* or mot
Ragi	*Kutki*	Niger
Gram	Wheat	Linseed
Cotton	*Jowar*	Groundnut
Groundnut	Cotton	*Jowar*
Sugarcane	Chillies	Paddy

In the Northern districts, the rotations are :

Crop	Rotations followed
Rice	Light soils-rice after rice Light bunded soils-rice followed by *utera* of leguminous crops or linseed. Heavy bunded soils-rice-wheat or any crops including gram, *masur*, *teora*, peas, etc., or linseed.
Jowar	*Jowar*-groundnut and cotton in cotton tract, and in non-cotton tract followed by *til*, sann, *tur*, *udid*, alternatively.
Wheat	Wheat mixed with gram. Wheat mixed with gram and *teora*, Wheat followed by leguminous crops as gram, *masur*, *teora*, peas, etc., then wheat followed by linseed and leguminous crops.
Gram	As shown under wheat.
Cotton	As shown under *jowar*.
Groundnut	As shown under *jowar*.
Sugarcane	Rotated with potatoes or vegetable crops or irrigated wheat.

In Eastern Berars, the rotations are :

(1) Cotton, *jowar*, groundnut. (2) Cotton, wheat, cotton, *jowar*. (3) Cotton *juar*. (4) Wheat, wheat, linseed, or gram.

In Western Berar, the rotations are :

(1) Cotton, *jowar*, groundnut. (2) In *ghat taluqs*, it is cotton ; *jowar*, cotton or groundnut, wheat. (3) In Pur valley it is cotton, cotton, wheat or *jowar*.

Bombay Province

The following rotations are selected as those largely prevalent, from among the districtwise rotations, furnished by the Director of Agriculture :—

Ahmedabad District	(A) First year—cotton, second year—*jowar*. (B) do. Cotton, do. *jowar*, third year-groundnut.

	(C) First year Cotton, *jowar* or *bajri*, second year—groundnut.
	(D) do. Cotton, second year—*bajri*, third year—groundnut.
Kaira District	*Bajri* mixture—*kodra* mixture—*bavto* mixture—dry tobacco.
Broach District	Cotton—*rabi jowar*.
	Cotton—*rabi jowar*—lang.
Panch Mahals	*Kharif* maize, *rabi* wheat and gram—groundnut—*bajri*—groundnuts.
Thana District	Rice after rice ; if there is moisture then gram, *tur* and *val* are taken in the *rabi*.

On Varkas land. *Rale* and pulses—*nagli* or *vari*—*niger*—fallow—fallow *Rale* and pulses—rice—*nagli* or *vari*—*niger*—fallow.

Central Division

(1) Rice and pulses in the same year
(2) Cotton—groundnut—*jowar*
(3) Cotton-groundnut-wheat or gram
(4) Sugarcane-cotton-*nilwa* in *kharif* and gram in *rabi*
(5) *Bajri*-groundnuts-cotton
(6) Sugarcane-ratoon-cotton in *kharif* and gram in *rabi*

Southern Division

(1) Rice—spelt wheat or gram
(2) Rice—rice or sugarcane, or rice in *kharif* and pulse in *rabi*
(3) Rice—irrigated *jowar* or chillies
(4) *Jowar*—cotton-wheat
(5) *Rabi* jowar-wheat and gram, pure or mixed with oilseeds like safflower
(6) *Bajri*—spelt wheat (under irrigation)
(7) *Bajri*—navane or *bajri*
(8) *Bajri*—*kulthi-kharif jowar*
(9) Ragi—*kulthi*, *save*, *nachani* or such millets
(10) Under canal irrigation—
  (*a*) Maize and sann in *kharif*-sugarcane
  (*b*) Maize and *tur* first year—maize, and sann in second, sugarcane in third
(11) *Rala*, followed by *kharif jowar* or pulses
(12) Wheat—*jowar* or cotton
(13) Wheat—irrigated cotton or chillies
(14) Groundnuts—*jowar* or cotton
(15) Groundnuts—irrigated spelt wheat

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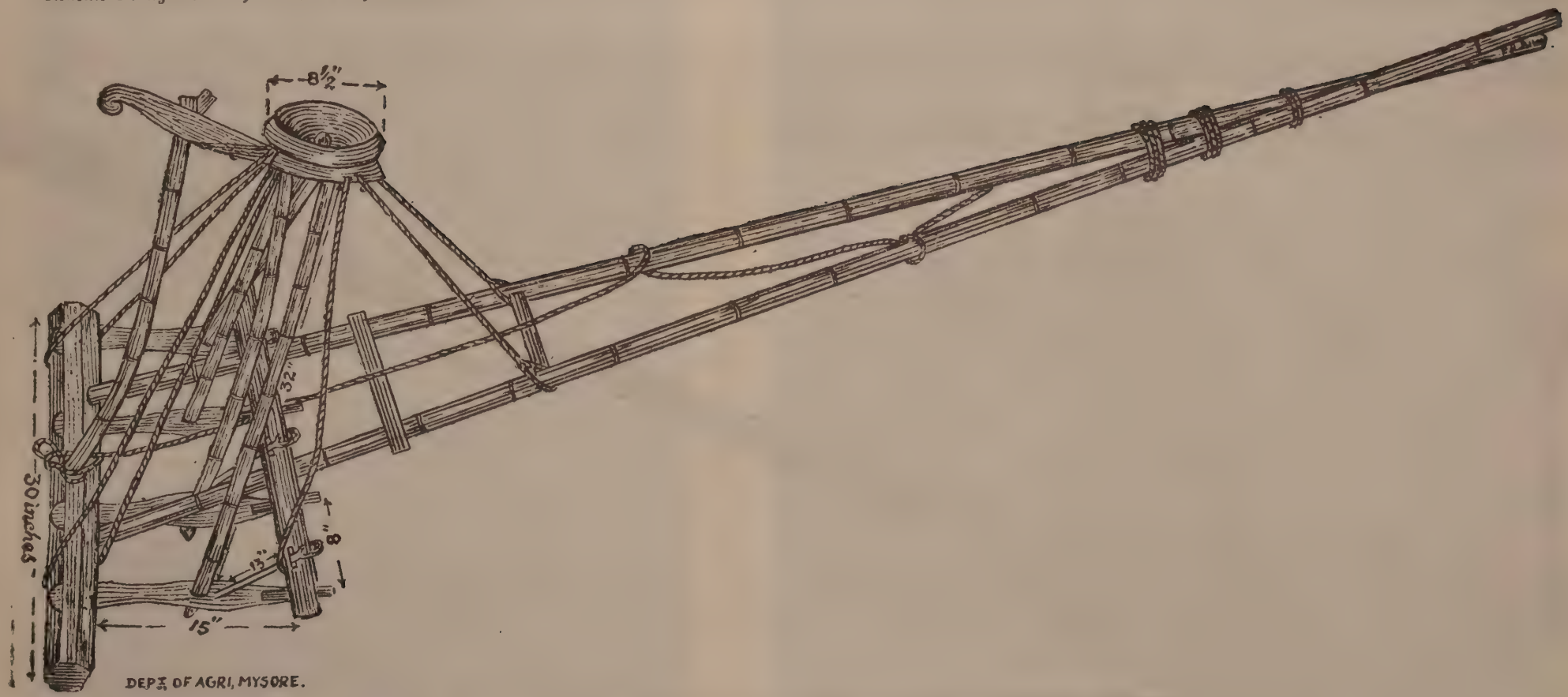

Fig. 1. Four-row drill, used for sowing rice (dry) and other large size seeds (Mysore)

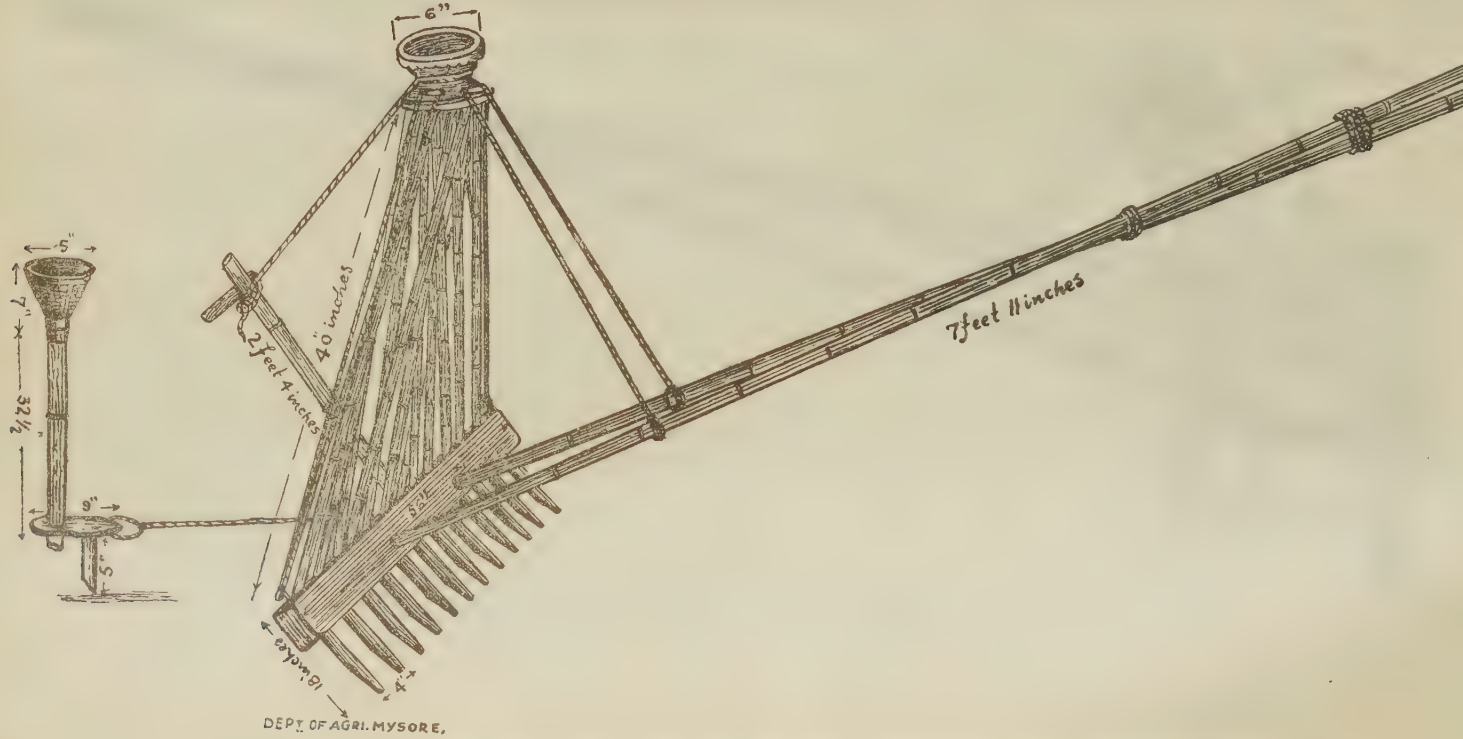

FIG. 2. The twelve-row seed drill for sowing *ragi*, with the one-row drill for sowing the mixed crop (Mysore)

Fig. 3. Gram with wheat border of linseed (Bihar)

Fig. 4. Wheat, mustard and peas

FIG. 5. Barley and peas from the Indian Agricultural Research Institute, New Delhi

FIG. 6. Barley and gram from the Indian Agricultural Research Institute, New Delhi

Fig. 7. *Rahar* and castor

Fig. 8. Tobacco and *bokla* (pulse)

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Reference to literature, arranged alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the year of publication title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state ' Original not seen '.

Sources of information should be specifically acknowledged.

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